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THE MINERALOGICAL SOCIETY

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EXCERPT MINUTES OF COUNCIL MEETING.

Held in the Apartments of the Geological Society, June 14, 1905.

Professor H. A. Miers, D.Sc., F.R.S., President, in the Chair.

A letter of resignation of Membership of Mr. W. W. Butler was read.

Mr. De Castro, Dr. Flett, Mr. Rudler, and Dr. Tutton were nominated o replace the Ordinary Members of Council retiring by seniority, amely Messrs. Harker, Pollard, Prior, and Herbert Smith.

GENERAL MEETING.

Held in the Apartments of the Geological Society, June 14, 1905.

Professor H. A. Miers, D.Sc., F.R.S., President, in the Chair.

Eighteen Members were present.

The following papers were read :—

1. The chemical composition of Lengenbachite : by Mr. A. Hutchinson.
2. The chemical composition of Hutchinsonite : by Dr. G. T. Prior.
3. The identity of the ancient Amiantos of Cyprus with Chrysotile : y Dr. J. W. Evans (p. 143).
4. The application of methods of descriptive geometry to the gnomonic rojection of crystals : by the same (p. 149).

Mr. D. F. Campbell showed a specimen of Dundasite from Wales p. 167), and the President three sealed tubes containing supersaturated lutions of sodium nitrate which, however much shaken, deposit no rystals until cooled below certain temperatures (p. 123).

EXCERPT MINUTES OF COUNCIL MEETING.

Held in the Apartments of the Geological Society, November 14, 1905.

Professor H. A. Miers, D.Sc., F.R.S., President, in the Chair.

Mr. Bernard Mouat Jones was elected an Ordinary Member of the ociety, and Professor H. Baumhauer of Freiburg, Switzerland, an onorary Member.

The following were selected as the dates of Meeting for the year 06 :—Tuesdays, January 23, March 20, June 12, November 13, the st to be the Anniversary Meeting.

The draft annual report of Council submitted by the Secretary was pproved.

ANNIVERSARY MEETING.

Held in the Apartments of the Geological Society, November 14, 1905

Professor H. A. Miers, D.Sc., F.R.S., President, in the Chair.

Twenty-five Members and one Visitor were present.

The election of Mr. B. M. Jones as Ordinary Member and of Professo H. Baumhauer as Honorary Member was confirmed.

The scrutineers reported that thirty-five voting papers for th election of Officers and Council had been returned to the Genera Secretary, and that the List as nominated by the Council was approved namely:—

President. Prof. H. A. Miers, M.A., D.Sc., F.R.S.

Vice-Presidents. Prof. W. J. Lewis, M.A., F.C.S.
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J. S. Flett, M.A., D.Sc., F.R.S.E
F. W. Rudler, I.S.O., F.G.S.
A. E. H. Tutton, D.Sc., F.R.S.

The following Annual Report of Council was read:—

The Balance Sheet for the year ending December 31, 1904, which ha already been published in No. 64 of the Journal, shows that the Asset of the Society (exclusive of the Library and the Stock of the Journal amounted to £682 8*s.* 3*d.*, and that the Liabilities amounted t £56 19*s.* 8*d.* The number of Life-Members on December 31, 1904, wa fifty-one; the value of the Stock invested in the names of the Trustee of the Society was on that date £569 1*s.* 10*d.*, corresponding t £11 3*s.* 2*d.* for each Life-Member.

During the Session 1904–5 the Society has lost no members either b death or resignation; three additional Ordinary Members (Mr. Barker

Mr. Woodgate, and Dr. Goodchild) have been elected. The total number of Members on November 13, 1905, was 123; of these nineteen are Honorary Members and 104 are Ordinary Members; of the latter fifty-one have compounded for the annual subscription.

Four Meetings have been held during the year, all in London, and (by kind permission) in the Apartments of the Geological Society, Burlington House.

Only one Number of the Journal, No. 64, published in May, 1905, has been issued during the Session. Three of the papers were descriptive of instruments; that of Mr. Hartley described a new device for separating minerals by means of heavy liquids; Mr. Herbert Smith's paper described an improved form of Refractometer; Dr. Evans explained some new forms of Quartz-wedge. Two papers of Mr. Hilton related to crystallographic projection; Mr. Solly described some new minerals from the Binnenthal; Mr. Currie and Mr. Thomas treated of Scotch Minerals, and Mr. Lindsey of Brookite from the Cleveland ironstone.

The Council has to congratulate the Society on its continued prosperity.

On the motion of the President, seconded by Dr. Scott, the Report was adopted.

A vote of thanks to the Council of the Geological Society for permission to meet in the Apartments of the Society was carried with acclamation.

The following papers were read:—

1. On a tabular crystal of white Diopside: by Prof. W. J. Lewis.

2. On a curious crystal of Pyroxene: by the same.

3. On a Carlsbad-twin of Albite: by the same.

4. The determination of the angle between the optic axes of a crystal in parallel polarized light: by Dr. J. W. Evans (p. 157).

5. Note on the formation of Gypsum crystals in a disused well at chemical works: by Mr. C. J. Woodward.

6. Note on the crystallization of drops, especially of potash-alum: Mr. Jacques Chevalier (communicated by the President) (p. 134).

7. On Ilmenite, Seligmannite, Marrite, Proustite, Trechmannite, and Hyalophane from the Binnenthal: by Mr. R. H. Solly (p. 184).

Specimens were exhibited in illustration of the various papers, and also a Turnerite from Switzerland by the Rev. J. M. Gordon, and Pitchblende from Cornwall by Mr. A. Russell.

GENERAL MEETING.

Held in the Apartments of the Geological Society, January 23, 1906.

Professor H. A. Miers, D.Sc., F.R.S., President, in the Chair.

Eighteen Members and one Visitor were present.

The following papers were read:—

1. Geikielite and the magnesium-ilmenite series: by Mr. T. Crook and Mr. B. M. Jones (p. 160).

2. Studies in Crystallization: by Professor H. A. Miers and Mr. J. Chevalier (p. 123).

3. On the determination of refractive indices by the method of minimum deviation: by Mr. G. F. Herbert Smith (p. 191).

Dr. J. W. Evans afterwards initiated a discussion as to the indication of the character of quartz-wedges and mica-plates by means of marks on them. Professor Miers illustrated his paper by means of the lantern; Messrs. Crook and Jones showed specimens illustrating the characters of Geikielite; and Mr. Herbert Smith submitted a diagram (Plate IV) useful for the determination of refractive indices without calculation.

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THE MINERALOGICAL SOCIETY.

No. 65. **May, 1906.** **Vol. XIV.**

COMMUNICATIONS FROM THE OXFORD MINERALOGICAL LABORATORY. No. VII.

1. On the crystallization of sodium nitrate: by Professor H. A. Miers, D.Sc., F.R.S., and Jacques Chevalier.

2. On the crystallization of potash-alum: by Jacques Chevalier.

On the crystallization of sodium nitrate.

By PROFESSOR H. A. MIERS, D.Sc., F.R.S., and JACQUES CHEVALIER.

[Read January 23, 1906.]

EXPERIMENTS made by Professor Miers and Miss F. Isaac[1] have shown how, by measurements of the refractive index, it is possible to determine for a supersaturated solution the temperature at which it passes from the metastable condition, in which it can only crystallize by inoculation with a crystal of the salt (or of a substance isomorphous with it), to the labile condition, in which it may (and often does) crystallize spontaneously. In a diagram in which concentrations are taken as ordinates and temperatures as abscissae the solubility curve represents the limit between the unsaturated and the metastable state; and the limit between the metastable and the labile state is represented by a similar curve, to which they have given the name 'supersolubility curve'.

When a cooling solution is shaken, the passage to the labile state is

[1] Journ. Chemical Society, 1906, vol. lxxxix, pp. 413–454.

generally marked by the appearance of a dense cloud of small crystals, but if there be crystals already present clouds may also appear in the metastable solution.

The present experiments were made with the object of ascertaining whether there is any difference in the mode of growth of crystals from a metastable and from a labile solution; what are the particular conditions which cause a labile solution to crystallize; at what parts of such a solution the first crystals appear and why; and how the clouds are produced.

The experiments are of three sorts :—

I. Test-tubes, immersed in a narrow glass trough filled with water at a known temperature, contain solution which is metastable at that temperature, and the growth and behaviour of an immersed crystal is watched by means of a microscope with its tube set horizontal, and the objective against the face of the trough. The tube may be plugged with cotton-wool, or the solution may be covered with a layer of oil at the same temperature, to prevent the access of crystalline germs from the air.

II. Drops of solution of such a strength as to be metastable at the temperature of the room are examined on a glass slide under the microscope until by evaporation, or by cooling, or both, they pass into the labile state. If it be desired to protect it from the air, the drop is enclosed by a cover-glass resting on a ring of Canada balsam, or of vaseline, surrounding the drop.

III. Solutions of known strength contained in sealed tubes are immersed in warm water, and are examined under the microscope while the water cools, in order to study their behaviour while at rest at known temperatures.

Such experiments might be carried on indefinitely, and are required for solutions of all sorts, since previous descriptions have not distinguished between the metastable and labile conditions.

The following experiments relate to sodium nitrate, because that substance has been most fully studied in the memoir referred to above, and because the problem is not complicated by the existence of two crystalline modifications or of salts containing different proportions of water.

I. *Experiments upon solutions in open tubes.*

One objection to the employment of a considerable volume of solution maintained at rest is the fact that, unless a long time be allowed for diffusion, different parts of the solution may be of quite different concentrations.

f, for example, sodium nitrate be dissolved at the bottom of a test-tube, nd care be taken not to shake the solution, the lower part of the liquid ay be supersaturated while the upper part is unsaturated. The solution ay be explored by an immersed crystal of the salt which can be watched nder the microscope and seen to grow while in the lower part, but to issolve while in the upper part of the tube; and sometimes quite a ell-defined, oscillating meniscus may be found between the two. It is ore than probable that one part of a solution may be in the metastable nd another part in the labile state, or that there may be some streams f labile solution in the metastable liquid.

When crystals grow in an ordinary metastable solution they seem to iginate either at the top or bottom of the liquid, or at both places; hen the solution is uncovered, close examination shows that they pro-ably originate at the surface and are carried to the bottom by their wn weight or by the circulating currents. Their origin at the surface ay be due to evaporation there, which reduces the solution locally to e labile state. If the liquid is exposed to the air, crystallization is so undoubtedly started in many instances by solid germs falling upon e surface. Attempts were made to prevent evaporation and access of erms by covering the liquid with a layer of oil at the same tempera-re; but even with this precaution crystals usually appear just below e oil before the solution as a whole passes into the labile state. rystals so small as to be almost invisible may also be seen to rise in the scending currents, and to remain at the surface until they have grown large that they fall by their own weight. In a metastable solution, erefore, crystals always originate at the margin of the solution, and it is st possible that the first crystals may appear at the bottom as well as at e top of the solution.

The following is a striking difference between the two sorts of solution. a crystal of sodium nitrate be immersed into the metastable solution, inute crystals at once form on it, all in parallel position; but if it be mersed into a labile solution the minute crystals which form upon it e in all sorts of positions and are not orientated as the parent crystal he crystals also appear at the same time upon the sides of the tube and roughout the solution). This appears to indicate that in the labile lution a cloud of minute rhombohedra produced by the introduction of e large crystal attach themselves to it and then continue to grow dly, whereas in the metastable solution the centres of growth are on the surface of the crystal. Precisely the same difference is ced when a cleavage piece of the isomorphous calcite is employed.

Again, if very minute crystals be quietly introduced into a metastable solution, a few other minute crystals appear in their neighbourhood while they are moving; but in a labile solution they produce a fine shower of crystals.

Clouds of small crystals are, however, not peculiar to labile solutions they may also be produced, though in a much less degree, in metastable solutions by moving a crystal of sodium nitrate to and fro in the liquid The moving crystal produces visible streams in its wake, and in these the small crystals make their appearance. When a metastable solution containing a few crystals is violently shaken, a cloud is formed; when a labile solution containing a few crystals is violently shaken, a much more dense cloud is formed and one which consists of much smaller crystals.

When crystals are introduced into the unsaturated solution, they are, of course, partly dissolved and become rounded; and they sometimes remain so when the solution passes into the metastable state, unless shaken. In one such experiment (49 per cent. solution) the rounded crystal was covered with small rhombohedra as soon as the liquid became metastable; but when moved suddenly (at 24°) to another part of the solution it shed a number of small crystals and ceased to grow; it only began to grow again (at its lower end) at 21°. Again, it is sometimes found that the edges and minute protuberances of a crystal introduced into the metastable solution remain unchanged, while the small crystals forming upon its surface in parallel positions are growing rapidly.

The following are the details of two experiments with introduced crystals:—

(1) A 47·6 per cent. solution (which becomes metastable at 24° C. and labile at 13½°), contained in a tube stopped with cotton-wool and immersed in water, was watched through the microscope. The temperature was lowered by the addition, from time to time, of cool water to that in the trough.

The temperature of the water being 24°, a sharp cleavage rhombohedron of sodium nitrate was suspended in the middle of the solution.

$t = 22°$: the crystal appears to be neither growing nor dissolving a few crystals have formed on the side of the tube just above the edge of the meniscus.

$t = 21°$: a small crystal has formed and is growing upon the top of the immersed rhombohedron.

$t = 20{\cdot}6°$: the small crystal is growing regularly and is now accompanied by a second; the parent crystal may be growing slightly.

$t = 20{\cdot}5°$: fresh crystals are growing on the top of the parent crystal

$t = 20{\cdot}4°$: fresh crystals are growing on the surfaces of the parent crystal, all in parallel position, and especially along the inequalities of the faces.

$t = 17°$: a small crystal detached from the parent rises to the surface of the liquid; at 16° the streams proceeding from the parent crystal take some of the small crystals to the bottom.

$t = 14°$: the solution has become labile, a shower of small crystals is falling from the top of the solution, from the edges of the tube, and from the parent crystal.

$t = 10°$: the parent crystal is covered with small crystals.

(2) A fresh cleavage piece of sodium nitrate was introduced at 35° into a 50·65 per cent. solution (which becomes metastable at 38°, labile at 29°), and suspended just below the surface. It begins to be slightly dissolved, small particles separate from it and sink to the bottom, and are growing there while the temperature is 34°. The crystal being slightly moved produces visible streams in the liquid, and in these new crystals appear; the parent crystal continues to dissolve; the minute particles which fall from it only become visible a short distance below it; no cloud is produced by gentle shaking of the tube; at 32° the crystal was removed and found to have rounded edges and corners. No cloud was produced by moderate shaking till 28·5°, when the solution had become labile.

Several experiments were made in which a metastable solution, covered with oil, was stirred by means of a glass rod, which had been immersed in it for a long time while the solution was cooling from a high temperature: this usually produced a cloud, but it is impossible to prove that it may not be due to crystals already forming at the surface of the liquid and set in motion by the rod, or forming upon the rod just above the part immersed.

Scratching the side of the tube with a rod produces crystallization along the line of the scratch in a labile, and perhaps also in a metastable, solution; but if the tube be scratched before the cooling solution has attained the metastable state no crystals appear upon the scratch. Is it not possible that the effect is due to crystalline material which the rod has picked up on its entry through the surface? It may be mentioned here in this connexion that crystals do not seem to form in sealed tubes at the points where they have been rubbed by enclosed fragments of glass.

When a number of crystals appear in a metastable solution they seem to be propagated from one another by means of the concentration streams proceeding from each crystal, and it may be because these carry away

the minute individuals which form upon the surface of the parent crystal. In a labile solution the streams are more active, and more general, and rapidly give rise to crystals of considerable size or to long needles.

Some attempts were made to introduce drops of labile liquid into a metastable solution, and in these experiments crystals seemed to be produced by the contact of the two liquids: but in all such experiments it is difficult to make sure that germs of solid crystals are not introduced at the same time, and it is possible that the crystallization is really due to these.

The whole process of crystallization and the formation of clouds may be beautifully shown by projection upon a screen, which renders it possible to watch the growth of individual crystals as they move through the liquid. By projection through crossed nicols the observations are made both more beautiful and more intelligible, owing to the polarization tints exhibited by the most minute crystals of sodium nitrate, which allow one to trace the increase in thickness of each rhombohedron as it rises or sinks through the liquid. A very common feature of this substance when growing in an agitated solution is the appearance, beside the ordinary rhombohedra, of fine hair-like crystals or rods. Projection upon the screen shows that these are only elongated rhombohedra growing rapidly in a vertical direction in the slender vertical streams of ascending or descending (perhaps labile) solution.

II. *Experiments with drops.*

When a crystal of sodium nitrate is introduced into a drop of the metastable solution it generally causes a few crystals to make their appearance at once in its immediate neighbourhood; the drops very often divide into two, and the portion which contains no crystals may remain without crystallizing until it reaches the labile state. When a crystal of sodium nitrate is introduced into a drop of the labile solution it causes the sudden appearance of crystals throughout the whole drop; if a portion separates, it also crystallizes at once.

In both cases a cleavage fragment of calcite produced exactly the same effect as a crystal of sodium nitrate.

The experiments are best performed by placing the drops on a slide close to the crystal, enclosing both with a ring of balsam or vaseline, and covering with a thin cover-glass. The drop is allowed to stand for a considerable time; the absence of crystals proves that it has not been contaminated by inoculation from the air, and the loose crystal may then be pushed in by means of a needle passed through the balsam.

If a drop be left to itself without the introduction of a crystal it will not crystallize until it passes into the labile state, when a number of crystals make their appearance and continue to grow rapidly.

When a drop is free to evaporate the crystals appear first in a ring round the edge. No doubt the drop is locally reduced to the labile state at the edge.

A curious feature in the metastable drop into which a crystal has been introduced, and one which is not in accordance with the statements generally made, is that the small crystals produced in the immediate neighbourhood of the large parent crystal may proceed to grow rapidly while the parent crystal itself does not increase in size.

III. *Experiments with sealed tubes.*

The tubes employed were about 10 cm. in length and about 1·4 cm. in internal diameter, and were two-thirds filled with solutions of known strength.

When the tubes were placed in a horizontal position, the first minute crystals generally made their appearance, shortly after the labile condition was attained, at the bottom of the tube, and almost at the same time (but usually a little later) upon the surface of the liquid. The crystals which floated on the surface united themselves in a chain parallel to the length of the tube. When the tube is in a vertical position, isolated crystals can be seen beginning to form almost simultaneously at the top and bottom of the liquid, and others may be seen falling near the sides of the tube.

In general it appears that the first crystals which form upon the surface appear at or near the edges of the liquid, and that those which float gravitate to the lowest part of the meniscus, thus forming a chain when the tube is horizontal. It is possible that most of the crystals which appear at the bottom of the tube have fallen thither from the surface, but perhaps before they are large enough to be visible. It is, however, certain that some of those which grow on the surface have been taken there from below by ascending currents. The weaker the solution the larger and less numerous are the crystals which form; with stronger solutions they are smaller and more numerous, and form more rapidly.

Unless the salt be completely dissolved crystals will, of course, appear as soon as the solution falls to the saturation temperature. They sometimes appear although there is no visible solid in the solution; but this is always due to the fact that the tubes have not been heated for a sufficiently long time or have been inadequately shaken while heating.

It requires prolonged heating and constant shaking to dissolve the last traces of salt.

On the other hand, if the tubes are kept at rest there is no reason why crystals should appear at the exact temperature at which the solution passes into the labile state. It is true that if the temperature be reduced very gradually the first crystals generally appear as soon as that state is attained if the tube be shaken, and give rise to a copious cloud. But if the tube be suddenly chilled it may be taken to a far lower temperature without crystallizing, and even then only a few crystals may appear, and may grow quietly unless the tube be shaken. Since in such experiments crystals do not usually appear unless either the tube contains some foreign substance, or has been warmed and shaken again while cooling, it is possible that the sudden chilling has only had the effect of reducing portions of the liquid to the labile state.

In general, if a solution be kept quiet, it is very difficult to distinguish between the metastable and labile states. For isolated crystals, which may appear spontaneously or have been introduced, may continue to grow independently in a uniform manner in either solution. It is only when the tube is shaken that a distinction can be observed. If the tube contains no crystals a cloud appears in a labile, but not in a metastable, solution. In a labile solution it is possible, by slightly moving a tube containing a crystal, to produce a fine cloud at a distance from the crystal: with a metastable solution this is not possible. If there be crystals present, the cloud produced by shaking a metastable solution is quite different in character from that of a labile solution. The former is thin and consists of comparatively few nuclei; the latter is dense. We distinguish them as a 'metastable cloud' and a 'labile cloud'.

In the production of these clouds the initial temperature seems to be an important factor: if the solution be reduced by sudden cooling from the metastable to the labile temperature, and then shaken, a dense labile cloud is produced: but if it be reduced to the labile temperature by sudden cooling from a higher temperature, and then shaken, a metastable cloud is produced. In these experiments, again, it is possible that though the solution is, in part at least, reduced to the labile temperature, it is not completely reduced to the labile state; for the process of crystallization resembles that in a metastable solution into which a few crystals have been introduced.

A number of experiments were made with tubes containing other substances in addition to the solution of sodium nitrate. In all these it

was found that a piece of calcite (either a cleavage fragment or a crystal) produces exactly the same effect as a crystal of sodium nitrate. It is, of course, impossible to introduce a crystal of sodium nitrate in the same way as one can an insoluble substance like calcite: but with care it is possible to leave a small crystal adhering to the top of the tube while the rest is completely dissolved in the lower part. As soon as the solution passes into the metastable state crystals begin to grow in parallel position on the calcite: if other substances appear to relieve the supersaturation like calcite, it is only because the sodium nitrate has not been completely dissolved, and their presence renders solution a little more difficult. If the solution has been complete, calcite is the only substance which has this power, as we have proved by comparative experiments on tubes of the same solution containing different mineral substances, examined side by side. Calcite appears to act even more energetically than sodium nitrate itself: for example, with a tube of 50 per cent. solution containing a piece of calcite in the liquid and crystals of sodium nitrate out of it, crystals began to appear on and near the calcite at 35°; when the liquid was brought into contact with the sodium nitrate the crystals produced in their neighbourhood did not grow so rapidly, and were not so numerous as those close to the calcite.

The crystals which form in a sealed tube at rest almost invariably exhibit a minute triangular speck on one face; and when crystals growing on the surface of the solution are watched from the time of their first appearance, this spot is seen to occupy the position of the original nucleus; it may be a cavity (hopper-structure) on the upper surface of the crystal, produced by the presence of solution round the crystal and absence of solution above it, as generally happens with floating crystals. This suggests that all these crystals have originated in the surface of the liquid.

IV. *General conclusions.*

We would not venture to draw any general conclusions from the preceding rather fragmentary experiments, were it not that the experiments upon sodium nitrate are, in general, confirmed by those upon other substances, although we have in the present communication confined ourselves to sodium nitrate.

The experiments show that the process of crystallization enables us to distinguish between the metastable and labile states, and so confirm the distinction which has been already established by means of the refractive index.

An aqueous solution, either by cooling without serious change of concentration, or by evaporation of the solvent without serious change of temperature, or by both, becomes supersaturated and passes first into the metastable state (in which it will only crystallize by inoculation with a crystal of the solute or of an isomorphous substance) and then quite suddenly into the labile state (in which it may crystallize spontaneously). Spontaneous crystallization in the latter is generally induced by shaking or by friction, but in any case it is started by introduction of a crystal of the solute or of an isomorphous substance; whereas the introduction of such a crystal into the metastable solution only produces a few crystals in its immediate neighbourhood.

In a metastable solution centres of growth are only on the surface of a crystal already present, in a labile solution they may be anywhere.

When a labile solution containing a crystal is shaken, a dense cloud of new crystals is produced, both by the contact of the crystal with fresh portions of the solution, and by the creation of fresh centres of growth at a distance from itself owing to the mere motion of the liquid.

The cloud which is produced when a metastable solution containing a crystal is shaken is not so easy to explain: but it is certain that a number of minute crystals grow on the surface of the parent crystal as soon as it is introduced: it is probable, therefore, that many of these get loose and become new centres of growth when the crystal is moved through the liquid; and even when the parent crystal is still, they may be swept away from it by the concentration streams.

We were at first inclined to think that a crystal can only grow in contact with a labile solution; that when a crystal is growing in a metastable solution this is only due to the liquid in contact with it being so concentrated as to be really labile; and that therefore the cloud produced by moving a crystal in a metastable solution is due to droplets of this enveloping halo of labile liquid getting loose, and becoming new centres of growth. Experiments made by one of us[1] upon the strength of the solution in contact with a growing crystal of sodium nitrate have, however, shown that this liquid is not labile but metastable. We are therefore led to the conclusion that the cloud is produced by the liberation, not of liquid, but of solid particles from the parent crystal: and that these solid particles exist has been proved above by direct observations.

The fact that the liquid in contact with the growing crystal is not labile, but metastable, explains another curious feature of the experiments. It seems strange that in a labile solution a crystal which has made its

[1] H. A. Miers, Phil. Trans., 1903, Ser. A, vol. ccii, p. 515.

appearance should continue to grow quietly, and that crystallization should not spread through the whole liquid which is *ex hypothesi* ripe for it. But this is prevented by the halo of metastable solution which surrounds the growing crystal and protects the labile solution from contact with the solid. The experiments seem to indicate that this is only true of a crystal which has appeared spontaneously in the solution, whereas a crystal *introduced* into a fully labile liquid starts crystallization throughout the liquid.

If this be true, then a crystal growing in a labile solution is surrounded by a halo of liquid less concentrated than the main mass; but a crystal growing in a weakly supersaturated metastable solution may be surrounded by a halo of more concentrated solution.

On the crystallization of potash-alum.

By Jacques Chevalier.

[Communicated by Professor Miers, and read November 14, 1905.]

As has been mentioned in the preceding communication, a supersaturated solution, which is cooling or evaporating, passes successively into the metastable condition, in which an introduced crystal can grow in it, and then into the labile condition, in which it may crystallize spontaneously. The transition is indicated by a sudden change in the refractive index of the solution. It seems possible that in these two distinct states of the solution there may be a difference in the mode of growth of the crystals. In the following experiments an attempt was made to find evidence of such a difference by the examination of thin drops of solution crystallizing under the microscope: and potash-alum was found to be a convenient substance for the purpose.

Preliminary experiments with drops of supersaturated solution of potash-alum showed that when a crystal of the same salt was introduced at the edge it became immediately surrounded by small crystals apparently detached from it, and that, after a few minutes, the remainder of the drop crystallized suddenly in the form of a very regular geometrical pattern consisting of a rectangular network of isotropic fibres. This change suggested that the two modifications might possibly correspond to the two states; further experiments were therefore made with solutions of known strength.

The solutions used generally were 19·75 per cent. solution (which passes into the metastable state at 40° C., and into the labile state between 25° and 28°); and 18 per cent. solution (which passes into the metastable state at 37°, and into the labile state between 24° and 21°).[1] After the salt had been completely dissolved, the solutions were kept in test-tubes plugged with cotton-wool, at a constant temperature of about 35° or 30° respectively. Drops were taken from the solution with a glass rod, and deposited without a cover-glass on a slide warmed to the temperature of the solution; both rod and slide having been sterilized by passing them through the flame of a Bunsen-burner. The solution chosen was such that the drop might be just metastable for the temperature of the room,

[1] These limits were determined by experiments with solutions contained in sealed tubes, being the temperatures at which such solutions crystallize when shaken.

nd it was watched under the microscope while becoming labile by vaporation.

ft was soon noticed that three sorts of crystals may be observed even n the same drop: namely ordinary octahedra, the rectangular network entioned above, and birefringent spherulites. I will denote these by ne letters *O* (octahedra), *R* (rectangular network), and *S* (spherulites). n octahedron, for instance, may be growing in one part of the drop, hile spherulites appear at the edges; again a drop inoculated with *O* ay deposit in places octahedra, whereas in other places, where the drop thinner and spherulites have begun to appear, it deposits the network, n which appear octahedral terminations. Closer examination showed at the coexistence of the three forms in the same drop is actually due differences of concentration between the different parts of the drop, pecially between the middle part and the edges.

The drops generally yield in succession spherulites or octahedra, and ter the rectangular network.

Spontaneous crystallization in the metastable and labile states.

(1) *The Spherulites.*—If the drop be left to itself, the spherulites (*S*) dinarily grow first, except in the case of a very small drop, which is ickly converted into an amorphous mass with a stippled surface.

In rather large drops a number of crystalline aggregates, identical with e 'cauliflower crystals' of Loewel[1], from which sheaves of birefringent terial radiate, are visible after a time varying generally from four to minutes: they appear all round the edges, especially after the drop, ing to evaporation, has begun to contract and to present uneven edges. ey spread little by little from the edge into the whole drop, which comes finally converted into spherulites and birefringent plates, with ne of the amorphous material between them. All spherulites present typical cruciform extinction, and some of them a spiral structure. drops placed on very hot slides nothing appears but amorphous wrinkled terial on the edges and small spherulites nearer the centre.

The spontaneous appearance of the spherulitic material may be considered as an indication of the passage into the labile state. For if drop taken from a solution, which is about to become labile at the perature of the room, be placed under a cover-glass resting on a ring vaseline so as to prevent evaporation, crystals do not appear until the perature is reduced, when the drop crystallizes entirely as spherulitic terial. The same result is obtained, provided sufficient care be taken,

[1] Loewel, Annales de Chimie et de Physique, 1855, vol. xliii, p. 416.

when the temperature of the room is below the labile point: as soon a the drop has cooled to the temperature of the room, spherulites appea throughout the whole drop. Cooling, therefore, produces the same effec as evaporation upon a drop which is just about to become labile, and th appearance of the spherulitic material marks the change.

(2) *The Octahedra.*—Octahedra, in general, only grow if they hav been introduced into the drop. It is true that cold drops often yiel octahedra at once, but these do not necessarily, as is the case with *S* appear on the edges, where the solution is presumably stronger: the may appear anywhere in it, and generally upon hairs or dust. The have either been introduced with the dust of the air or originate fro crystalline germs transferred with the drop from the test-tube. A meta stable drop, when free from germs and kept covered or sealed, neve deposits octahedra; nor does it when it is cooled to the labile tempera ture, in which case spherulites only form. But if the drop originall contains one or several crystalline germs of alum, regular octahedr form little by little, and may continue to grow so rapidly that the dro never passes into the labile state in which *S* and *R* may appear.

(3) *The Rectangular Network.*—When the growth of octahedra i a metastable drop has not been very rapid or widely spread, th isotropic rectangular network may appear in parts of the solutio which have remained uncrystallized. As a rule this rectangular net work only appears after *S* has formed. It spreads round the edge and, in the case of a thin drop, all over the drop. After a while becomes white and opaque, and, at the same time, separates from th spherulites and from introduced crystals.

The rectangular network is produced by the introduction of a fragme or germ of octahedral alum into a drop from which *S* is growing. generally makes its appearance in drops which already contain *S*, bu some experiments indicate that it may appear spontaneously in dro which contain no crystals.

The supersaturated drops therefore behave differently according they are in the first state, in which no crystals grow spontaneously, in the second state in which *S* may, and does, appear by itself. Th first is the metastable, and the second the labile, condition with referen to octahedral alum.

Effect of stirring.

(1) Stirring of drops free from crystals:—

(*a*) *Metastable.*—Stirring with a clean rod metastable drops in whi there is nothing visible, produces no effect.

(*b*) *Labile.*—Stirring a drop in which a few spherulites are growing makes a number of minute spherulites appear. Sometimes the middle part of the drop separates, and becomes suddenly converted into the amorphous stippled material.

(2) Stirring of drops in which octahedra are growing:—

(*a*) *Metastable.*—In a large drop in which some introduced octahedra are growing the crystals, when moved with a clean rod, leave a train behind them; the germs thus formed continue to grow individually, with a cluster of minute particles close to them. Stirring at a distance from the crystals, however, produces no effect.

(*b*) A few minutes later, when *S* begins to appear at the edges, the same drop is stirred again: a cloud of particles is suddenly produced throughout the drop, and chains of minute octahedra extend in a remote portion of the drop which had been clear; fresh crystals also appear in the solution further on in the direction along which the crystals grow.

(*c*) *Labile.*—An octahedron which is growing in the middle of the drop being moved rapidly with a clean rod while *S* is appearing on the edge itself makes the network *R* to spread round the edge.

Inoculation of metastable and labile drops with the different modifications.

(1) *Metastable drops.*—If a drop in which nothing is visible be inoculated with *S*, the spherulite, when placed in the middle of the drop where the solution is more dilute, generally disappears. When placed at the edges it yields minute octahedra.

When a metastable drop is inoculated with *O* or *R*, octahedra are produced: they spread at once from the fragment of *R* or from the introduced *O* in the part of the drop which is in contact with it.

(2) *Labile drops.*—In a drop in which *S* is just starting to form, a small spherulite being introduced makes the amorphous material appear round it; new spherulites are also formed. Very often some long sheaves of isotropic material spread from them, which, after a while give rise to the rectangular network.

If the drop be inoculated with *O* or *R*, or even, as it seems, with a drop of strongly supersaturated solution of potash-alum, the geometrical net work at once spreads over the whole drop.

(3) It sometimes happened that alum crystals, either *O* or *R*, introduced into a drop where nothing had yet appeared, made the drop

crystallize in the network. As I supposed this to be due to the fact that the drop was just passing into the labile state, the experiment was repeated with drops which were certainly metastable. In these, octahedra alone appeared, never the rectangular network.

The different modifications and their effect upon each other.

It is probable that we have to do with two varieties of potash-alum: *S* and the birefringent plates being a less hydrated variety; whereas *R* and *O* are the ordinary hydrated alum, which has crystallized in different forms owing to the different conditions of the solutions. The next step is to examine more closely the different modifications and their relation to each other.

A curious effect is the frequent solution of *S* by *O*. Thus in a drop in which a single large octahedron was growing at one side of the drop, while *S* appeared at the other side, it was noticed that, as the alum crystal advanced near to a group of birefringent plates, the liquid surrounding the alum dissolved away the plates. As soon as the octahedron touched the birefringent sheaf, the cubic network started from the point of contact and ran round the whole drop, becoming lined on the inside with octahedral terminations.

This shows that the zone of solution in contact with an octahedron in a labile drop (where *S* is growing) is metastable (since it dissolves *S*). An alum crystal growing in a metastable solution is surrounded, as Professor Miers has previously proved, by an envelope of liquid which is more strongly supersaturated, but is still metastable for alum. When the solution passes into the labile condition, so that the sphero-crystals begin to appear, the alum crystals, instead of producing the network characteristic of that stage of supersaturation, continue to grow unchanged: this indicates that they maintain around them a zone of metastable liquid, which isolates them from the remainder of the drop, and prevents them from starting the network.

This very interesting fact and the conclusions it suggests were confirmed by many experiments. Thus:—

(1) An octahedron which has been growing in a drop from the beginning, and did not start the network even after a number of spherulites had appeared, being taken out and immediately reintroduced into the drop, or rapidly moved in it, makes it at once crystallize in the network.

(2) A fragment of octahedral alum being introduced into a labile

drop in which an octahedron is growing and which contains a foreign substance (e.g. corundum), causes the network to spread throughout the drop: it surrounds the other substance completely, but it stops before reaching the octahedron, delineating quite clearly in that way the zone of metastable solution in which the network cannot grow.

(3) The network, at the place where it stops round *O*, grows little by little in octahedra, characteristic of a metastable solution, just as it ordinarily does towards the centre of the drop where the solution is more dilute than at the margin.

(4) When a drop, in which *O* has been growing, suddenly develops the network, it is probably because the zone of metastable solution round *O* has broken at some point, so as to allow a portion of the octahedron to come in contact with the labile solution. This happened, for instance, after the octahedron had touched the birefringent plates, or when a sudden movement had been caused in the liquid, by introduction of a foreign substance, or by stirring, &c. Thus, beautiful rectangular lines may spread from an extremity of *O*, which becomes at once enveloped by them; but the network stops before it reaches the other portions of the same octahedron.

The spherulitic material *S* is certainly more soluble than the octahedra, since it is dissolved by the solution in which *O* is growing. And yet it is a less hydrated alum. When breathed on or simply exposed to moist air the spherulites become uniformly isotropic, and shortly afterwards begin to crack and become white and opaque. This change of birefringent into isotropic material is due to the conversion of *S* into *O*, as shown by various experiments: thus a hot solution on a hot slide solidified suddenly as an amorphous mass in which spherulites rapidly developed; addition of water produced a fine crystallization of *O*: and as it spread over the mass the network suddenly appeared.

Again, a drop *B* was placed beside a drop *A*, three minutes after *A* had been placed on the slide. The drop *A* crystallized in spherulites all round the edges, with amorphous stippled material in the middle. About the same time spherulites appeared in the small channel of liquid joining *A* and *B*: when they reached *B* they were suddenly transformed into octahedra, and the network immediately spread in *B* at the edges, with large octahedral terminations growing towards the inner part of the drop. This indicates that the spherulites may become transformed into octahedral alum by contact with a more dilute solution and may so inoculate it.

The change of birefringent *S* into isotropic *O* was watched by immersing

a fragment of a well-formed spherulite in a small drop of water: it at once became isotropic and began recrystallizing on its surface in the octahedral modification, the centre becoming more and more brown and opaque; the whole ultimately became converted into octahedra, but some of these were fringed with birefringent threads as there was probably not enough water to transform it entirely into ordinary alum.

The material of the rectangular network *R* is undoubtedly cubic: it presents a very perfect cubic structure. When a particle of it is introduced into a labile drop, a uniform network spreads over the whole drop, and the fibres remain constant in direction. The crystals when examined between crossed nicols, always proved to be isotropic. *R* becomes white and opaque after a time, owing to the development of cracks proceeding both from the centre and from the edges: this generally happens when the network presents radial groups of rectangular fibres, differently inclined to each other; when it is uniform it does not always break up. The opacity (as also that of *S*) disappears when *R* is immersed in oil, showing that it is only due to cracks.

R is, therefore, ordinary alum which is in a state of strain, owing to its rapid crystallization. The whole difference between *R* and *O* is explained by their mode of crystallization: octahedra only form in a metastable solution; they cannot appear if not introduced, and only grow individually by separation of crystals from an already formed crystal. *R* only starts in a labile drop: it is a parallel growth of *O* extended along the axes of a cube, and in the metastable parts of the solution it terminates in octahedra.

Evidences of different behaviour in the metastable and labile conditions.

From these experiments it appears that a supersaturated drop of potash-alum, which is either cooling or evaporating, or both, passes successively into two different states: one in which no cubic crystals appear unless introduced; but an introduced crystal grows and reproduces itself, either in its immediate neighbourhood, or, when stirred, in all parts of the drop. This is the metastable state. The crystalline form proper to this state is the common octahedral alum: *R* or *S* if introduced yield *O*. The second state is one in which birefringent sphero-crystals may, and do, form spontaneously; or an introduced particle of octahedral alum sets up at once, throughout the whole drop, a very perfect microcrystalline structure, in which the fibres are parallel to the axes of the cube, and the crystals are isotropic.

Now these two events, the spontaneous production of *S*, and the appearance (whether spontaneous or induced) of the rectangular network *R*, always occur in the same stage: *R* can only be started when *S* has already appeared, or when it is about to appear, and it can in fact be produced by inoculation with *S*. On the other hand, birefringent crystals only grow in a state of solution for which *R* is the characteristic crystalline growth. No local formation of *O* is possible in a solution from which *S* is growing: when *O* is found in such a drop it is because it has grown unchanged from the precedent metastable state, preserving round itself a zone of that solution; *O*, if introduced into the drop, yields the rectangular network.

Therefore *S* and *R* may be taken as indicative of the labile state of the solution: they present the two distinctive marks of a labile solution, namely, spontaneous crystallization, and a diffused growth indicating a sudden change throughout the whole liquid.

The only difficulty is that the passage into the labile state is not marked by the spontaneous appearance of the substance (ordinary alum) with regard to which the solution becomes labile; it is always the birefringent variety, more soluble and less hydrated, which appears spontaneously in the labile solution. This may be explained by supposing, either that the solution becomes labile for the one just before it becomes labile for the other, or that the birefringent modification, although it is less hydrated, crystallizes more easily from a solution which is labile for both, than does the ordinary hydrated and isotropic modification.

It is interesting to compare the behaviour, in a test-tube, of the solution from which the drop has been taken, with the behaviour of the drop itself. The introduction and moving of an alum crystal in a tube of labile solution produces the kind of cloud that has been described in reference to sodium nitrate, and which we called a 'labile cloud'; in the drop it produces *R*; so that the labile cloud in a large volume of liquid exactly corresponds to the network in a thin layer of the same liquid.

The rectangular network is not, therefore, an abnormal growth, due to the physical condition of drops. No doubt its dendritic aspect, and the extreme rapidity of its propagation in certain directions may be due to the thinness of the drop: but it corresponds to the labile cloud in larger volume of solution, and both are fully accounted for by the greater concentration of the liquid. The geometrical arrangement of *R* is a result of the crystalline structure of the cubic system. It is just possible (see experiments quoted above, p. 140) that the solution, when

passing into the labile state, may be arranging itself, before the appearance of the network, along certain directions related to the crystalline structure of the substance dissolved.

Note on inoculation with other materials.

This led me to think that, besides potash-alum and the substances isomorphous with it, other mineral substances might possibly have an influence on the crystallization of a labile drop of potash-alum solution. A great many experiments were made in order to ascertain this influence. The general results may be recorded here, although they require further confirmation before any decisive conclusion can be drawn from them.

Spinel, galena, and fluor, introduced into a drop of labile 19·75 per cent. solution produced the rectangular network, and the fibres of the latter appear sometimes to be parallel to the axes of the introduced crystal. Minerals of lower symmetry, such as blende, pyrites, and cuprite, do not cause the network to appear. With a weaker solution or a lower temperature, the network may be produced by inoculation with all these minerals as also with garnet, leucite, corundum, bismuth, quartz, topaz, and gypsum, but not with mica or glass.

But in all the experiments galena operated far more readily than any of the other substances in producing the rectangular network in a labile drop, and succeeded where they failed.

In metastable drops, on the other hand, topaz and (even more conspicuously) thorianite, which have little effect on labile drops, cause the appearance of octahedra far more readily than the other minerals, even than galena, which in fact has no such action in a metastable drop.

Comparative experiments suggest that in the labile solution the action of the introduced crystal may depend mainly upon its symmetry, whereas in the metastable solution it may depend more upon other factors.

The experiments described in this paper were carried out in the Mineralogical Laboratory of the Oxford University Museum, at the suggestion of Professor Miers.

The identity of the Amiantos or Karystian stone of the Ancients with Chrysotile.

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[Read June 14, 1905.]

FLEXIBLE mineral fibres appear to have been well known to the Greeks, who spun them into thread, which they wove into cloth or employed as wicks for lamps.

Pausanias, who lived in the second century of the present era, tells us that Kallimachos made for the statue of Minerva in the Acropolis at Athens a lamp of gold, the wick of which was of 'karpasian flax', which he states is the only flax inconsumable by fire.[1] Some have interpreted the words 'karpasian flax'—*λίνον καρπάσιον*—as meaning mineral flax from the Karpasos, the north-eastern promontory of Cyprus, but apart from the fact that there is no record of the occurrence of asbestiform minerals in that locality, it seems clear that the word *καρπάσιος* is derived from *κάρπασος* (feminine in the singular, but neuter in the plural *κάρπασα* or *κάρβασα*), which properly signifies cotton, being identical with the Sanskrit *ḳârpâsâ*, though it has been used for a fine variety of flax produced in Spain, as well as for other European plants. The mineral used in the sacred lamp was therefore presumably similar to cotton in softness and fineness. Nothing is said as to the locality from which it was obtained, but it was probably the produce of the quarries near Karystos, at the southern end of Euboea, which appear to have been the best known source of flexible mineral fibres in ancient times. They were in fact generally referred to as the Karystian stone (ὁ *Καρύστιος λίθος*).

[1] *Καὶ οἱ λίνου καρπασίου θρυαλλὶς ἔνεστιν, ὃ δὴ πυρὶ λίναν μόνον οὐκ ἔστιν ἀλώσιμον.* Pausanias, *Ἑλλάδος Περιήγησις, Ἀττικά*, chap. 26.

Strabo, who wrote in the beginning of the first century, tells us that in Karystos occurs the stone which is carded and woven to form handkerchiefs[1]; and, like almost all ancient writers who refer to asbestos, he states that the fabrics formed of it were cleansed by casting them into the fire.

Solinus states that Karystos possesses, among other marvels, cotton which stands fire.[2]

The quarries near Karystos appear, however, to have become exhausted, for we read in Plutarch (50–139 A.D.) that, at the time when he wrote, it was not long since the quarry had ceased to yield soft tissues (*μηρύματα*) of stone which could be drawn out into the form of thread[3]; and after referring to their use in making handkerchiefs and nets, he states 'that they, the *μηρύματα*, have now disappeared and scarcely more than fibres or slender hairs are embedded in the rocks of the quarries.'[4]

The rocks round the modern town of Karystos consist of crystalline schists, while one and a half hours to the east are two exposures of serpentine[5], so it is not improbable that the asbestos was really chrysotile, the fibrous variety of serpentine.

The only other locality, from which mineral textile fibres are said to have been obtained in ancient times, is the island of Cyprus. One of the earliest writers on minerals was Sotakos (Σώτακος or Τάκος), who is several times referred to by Pliny. In an extract from his book Περὶ λίθων, which has been preserved to us by Apollonius Alexandrinus Minor, he states that 'the stone called the Karystian has woolly and skin-like growths from which handkerchiefs are spun and woven, and they also twist wicks from it.'[6] After describing its incombustible character, he

[1] Ἐν δὲ τῇ Καρύστῳ καὶ ἡ λίθος φύεται ἡ ξαινομένη καὶ ὑφαινομένη, ὥστε τὰ ὑφάσματα (v. l. ὕφη) χειρόμοκτρα γίγνεσθαι. Strabo, Γεωγραφικῶν, Bk. x, chap. 1, par. 6.

[2] 'Carystos aquas calentes habet (Ellopias vocant), et Carystias aves quae flammas impune involant, carbasa etiam quae inter ignes valent.' An editor has unnecessarily altered 'valent' to 'lavant'. C. Julius Solinus, 'Polyhistor,' chap. 11, par. 15.

[3] Καὶ μετάλλων ἴσμεν ἐξαμαυρώσεις γεγονέναι καινὰς ὡς . . . τῆς τ' ἐν Καρύστῳ πέτρας, χρύνος οὐ πολὺς ἀφ' οὗ πέπουται μηρύματα λίθων μαλακὰ νηματώδη συνεκφέρουσα. Plutarch, Τὰ Ἠθικά, Περὶ τῶν ἐκλελοιπότων χρηστηρίων, Bk. ii, 434 *a* (edition 1796, vol. iv, p. 772).

[4] Νῦν δὲ ἠφάνισται, καὶ μύλις οἷον ἶνες, ἢ τρίχες ἀραιαὶ διατρέχουσιν ἐν τοῖς μετάλλοις (loc. cit.). Literally, 'run through in the quarries.'

[5] Friedrich Teller, 'Der geologische Bau der Insel Euboea.' Denkschr. k. Akad. Wissensch. Wien, Math.-Naturw. Classe, 1880, vol. xl, p. 153.

[6] Ὁ Καρύστιος λεγόμενος λίθος ἐπιφύσεις ἔχει ἐριώδεις καὶ χροώδεις, ἐξ οὗ νήθεται καὶ ὑφαίνεται χειρεκμαγεῖα, στρέφουσι δὲ ἐξ αὐτοῦ καὶ ἐλλύχνια. Apollonius Alexandrinus Minor or Dyskolos, Περὶ κατεψευσμένης ἱστορίας, chap. 36. The word χροώδεις does

continues: 'This stone is produced in Karystos, from which it took its name, and there is much in Cyprus on the left hand of those travelling down from Gerandros as if going to Soloi, under the rocks or cliffs of Elmaion.'[1]

Dioscorides (first century A. D.) refers to the occurrence of the 'amiantos stone' (*λίθος ἀμίαντος*) in Cyprus. He states that it resembles alum-shale[2], and is woven into incombustible fabrics.

Pliny the Elder (23–79 A. D.), who apparently drew his information from the same source as Dioscorides, states that amiantos resembles alum-shale and does not suffer by fire.[3] Elsewhere, in the portion of his Natural History devoted to plants[4], he describes an incombustible fibre under the name of asbestos. He states that it grows in Indian deserts scorched by the sun where no rain falls.

In modern times travellers from the sixteenth century onwards have referred to the existence of abandoned mines of asbestos in Cyprus near the village of Paleandros or Pelendria to the south-east of Mount Troodos, and some mention a village or district known as Amianto.[5] The mineral is stated to be dark green in colour and shining, thus resembling chrysotile more than the asbestos of mineralogists. Gaudry (loc. cit.) also refers to the occurrence of asbestos, and Bergeat[6] expressly mentions that the serpentine is penetrated by veins of chrysotile, though he does not refer to the fact of their having been worked.

In the map of the island surveyed by Lord (then Captain) Kitchener the stream flowing southward to the east of Pelendria is named Amiandos, and a locality on it is described as Mylos tou Amiandou (the Mill of the Amiandos), probably the site of a former watermill. There is apparently no village or district known as Amiandos or Amianto.

not appear to occur elsewhere; it has been translated 'coloured' instead of 'skin-like'.

[1] *Γίγνεται δὲ ὁ λίθος οὗτος καὶ ἐν Καρυστῷ μέν, ἀφ' οὗ καὶ τοὔνομα ἔλαβεν. Πολὺς δὲ ἐν Κύπρῳ καταβαινόντων ἀπὸ τοῦ Γεράνδρου ὡς ἐπὶ Σόλους πορευομένοις ἐν ἀριστερᾷ, τοῦ Ἔλμαίου ὑποκάτω πετρῶν* (loc. cit.).

[2] *Λίθος ἀμίαντος γεννᾶται μὲν ἐν Κύπρῳ στυπτηρίᾳ σχιστῇ ἐοικώς.* Dioscorides, *Περὶ ὕλης ἰατρικῆς*, Bk. v, par. 156.

[3] 'Amiantus, alumini similis, nihil igni deperdit.' Caius Plinius Secundus, 'Historia Naturalis,' Bk. xxxvi, chap. 31.

[4] op. cit., Bk. xix, chap. 4. See also Bk. xxxvii, chap. 54.

[5] J. A. Gaudry, 'Géologie de l'Île de Chypre,' Mém. Soc. Géol. de France, 1862, sér. 2, vol. vii, p. 269; Eugen Oberhummer, 'Die Insel Cypern: Part 1, Quellen-kunde und Naturbeschreibung,' München, 1903, p. 188.

[6] Alfred Bergeat, 'Zur Geologie der massigen Gesteine der Insel Cypern,' Min. petr. Mitt. (Tschermak), 1892, vol. xii, p. 293.

I am indebted to Professor Wyndham Dunstan for the opportunity of examining some of the mineral from the ancient mines on the south-east of Mount Troodos. It is similar in appearance to the Canadian chrysotile, the principal asbestos of commerce, and like it has its fibres at right angles to the veins in which it occurs, but it is shorter in staple than most specimens from the quarries at Thetford or Black Rock. It is pale green in colour, but shows no perceptible pleochroism. It has an extinction parallel to the fibre, the light vibrating in that direction having the least velocity. After drying in a hot air bath it is strongly stained by rhodamine.

An analysis[1] by Mr. G. S. Blake, of the Scientific and Technical Department of the Imperial Institute, gave the following result. The theoretical composition of the mineral and an analysis of a specimen from Broughton near Thetford, Quebec, are added for comparison.

	Near Mount Troodos, Cyprus.	Broughton, Quebec.	Theoretical composition.
SiO_2 ...	40·54 ...	40·57 ...	43·48
Al_2O_3 ...	1·09 ...	0·90 ...	—
FeO ...	4·87 ...	2·81 ...	—
MgO ...	39·02 ...	41·50 ...	43·48
H_2O (+100° C.) ...	13·47 ...	13·55 ...	13·04
H_2O (−100° C.) ...	1·13 ...	— ...	—
	100·12	99·33	100·00

The mineral has therefore the composition of a somewhat ferruginous serpentine ($H_4Mg_3Si_2O_9$).

There can be little doubt that the material examined came from the locality referred to by Sotakos. Unfortunately, neither Elmaion nor Gerandros is referred to by other classical authors, and the names are no longer in use. Oberhummer[2] suggests that the former is the peak to the east of Mount Troodos, known as Adelphi or Madhari, and that Gerandros is represented by the mediaeval and modern Paleandros[3] or Pelendria.

[1] Bulletin of the Imperial Institute, 1905, vol. iii, p. 281.

[2] loc. cit. and 'Studien zur alten Geographie von Kypros,' Abhand. aus dem Gebiet der klassischen Altertums-Wissenschaft, W. von Christ dargebracht, München, 1891, p. 102.

[3] Possibly Paleandros represents a play on words on the original name of the village which had, it need scarcely be said, no connexion with γῆρας, old age. The form 'Paleandros' is used by G. Mariti, 'Voyage dans l'isle de Chypre,' 1791, vol. i, p. 27.

At the present day the natives of the island call the mineral παμπακόπετρα, or cotton-stone, which recalls the κάρπασος of the ancients. Amiandos is said also to be used.[1] The correct expression in modern Greek is ἀμίαντος λίθος, which is practically the form used by Dioscorides; but in the latter part of the eighteenth century the term 'caristia' was still employed.[2]

The modern use of both asbestos and amiantos in the sense of flexible mineral fibres appears to be due to Pliny, who unfortunately seems to have been much worse informed on the subject than his contemporaries or his predecessors. The employment of the word asbestos in this sense seems to have been quite unwarranted. It signifies 'unquenched by water', and in both ancient and modern Greek is appropriately applied to quicklime. At the time when Pliny wrote the usual term for flexible fibrous minerals was, as we have seen, 'Karystios lithos,' though 'lithos amiantos' appears to have been occasionally, but not always, applied to chrysotile from Cyprus. Amiantos means 'untainted', and may have been applied to the mineral because it was cleansed by fire, a recognized symbol of purification in religious rites. This is the accepted view, but I cannot help thinking it possible that the name was first given to the stream which still retains it, for it is an epithet that was frequently applied to water, and that it was afterwards transferred to the mineral found in the vicinity.

It is, as we have seen, probable that not only the mineral from Cyprus, but also that from Karystos was really chrysotile, and that in ancient as well as in modern times it was fibrous serpentine, and not fibrous tremolite, that was mainly employed for spinning and weaving.

The use of the word 'amiantos' in modern times presents some points of interest. In the Romance languages it has taken, to a large extent, the place of asbestos, while by the early German and French mineralogists[3] it was restricted to the finer and more flexible forms which included what is now known as chrysotile-asbestos, and they would undoubtedly have described the mineral from Cyprus under that name. On the other hand, it was scarcely used at all in the language of English science till Mr. George P. Merrill, the mineralogist to the

[1] C. V. Bellamy and A. J. Jukes-Browne, 'The Geology of Cyprus,' Plymouth, 1905, p. 63.

[2] G. Mariti, loc. cit.

[3] L. A. Emmerling, 'Lehrbuch der Mineralogie,' 1793, vol. i, p. 39; and R. J. Haüy, 'Traité de Minéralogie,' 1801, vol. iii, p. 247.

National Museum at Washington, applied it to the soft flexible varieties[1] of chrysotile which are commercially known as asbestos, and there is much to be said for this use of the word.

I am indebted to Mr. G. F. Hill, of the Coins and Medals Department of the British Museum, for valuable criticism and advice from the standpoint of Greek scholarship.

[1] George P. Merrill, 'Notes on asbestos and asbestiform minerals,' Proc. U.S. National Museum, 1895, vol. xviii, pp. 281, 292. He employs the form 'amianthus', but there is no philological warrant for the insertion of the *h*.

Gnomonic Projections on two planes.

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[Read June 14, 1905.]

THE gnomonic projection in which the faces of crystals are represented by the points where their normals through a fixed point—the centre of projection—meet a plane—the plane of projection—is already widely used by crystallographers. I propose in the following pages to show the advantages of the simultaneous use of two such planes of projection.

It is in most cases convenient for the two planes to be at right angles, and for the centre of projection to be at an equal (unit) distance from each. Circumstances, however, in some cases render it desirable to vary these conditions. When the planes are at right angles, one may conveniently be described as the horizontal plane, and the other as the vertical plane.

In the diagrams, the projections of face-normals, and other points, on the horizontal plane are denoted by capital letters, and those on the vertical plane by small letters. Projections of zone-planes, and other lines, on the horizontal plane are represented by continuous lines, or, if there be two successive positions of the horizontal plane, those on one by continuous and those on the other by discontinuous lines; similar projections, and other lines, on the vertical plane are represented by lines of dots. The word projection, except where otherwise stated, is used throughout this paper in the sense of gnomonic projection.

The centre of projection is always designated by C, the foot of the perpendicular from it on the horizontal and vertical planes by P and p respectively, and the base-line or line of intersection of the horizontal and vertical planes by XX'. The perpendiculars from P and p on the base-line meet it at the same point M, and are ordinarily of unit length (12·5 mm. in the accompanying figures).

(1) If the projection of a zone-plane on the horizontal plane be given,

the projection on the vertical plane can be obtained by the following construction :—

Let TU (fig. 1) be the projection on the horizontal plane and let it meet XX' in U. Draw PQ parallel to XX' and meeting TU in Q, and QR at right angles to XX' and meeting it in R. Then the line pR is parallel to the line CQ (not shown in the diagram) in which the given zone-plane is intersected by a plane through C parallel to the vertical plane. The same zone-plane will intersect the vertical plane in a parallel line, for the lines in which two parallel planes are intersected by a third plane are parallel to one another. If therefore a line Ut be drawn parallel to Rp it will represent the projection of the given zone-plane on the vertical plane.

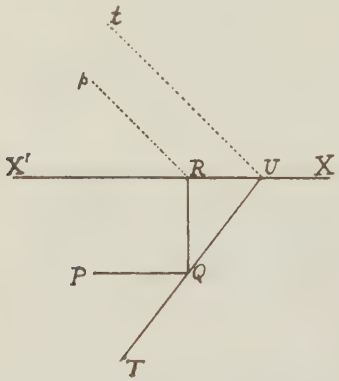

Fig. 1.

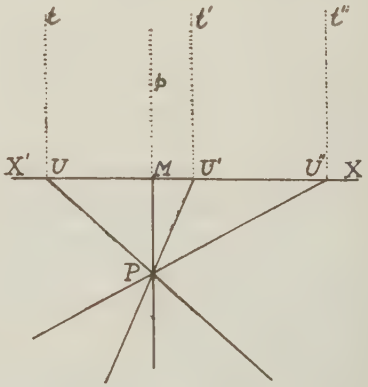

Fig. 1 a.

If the projection of a zone-plane on the horizontal plane pass through P (fig. 1 a), R will be at M on the straight line joining Pp, and the projection on the vertical plane will be at right angles to the base-line XX'. Vice versa, if the projection on the horizontal plane be at right angles to the base-line, the projection on the vertical plane will pass through the point p.

If the projection on the horizontal plane be parallel to the base-line the projection on the vertical plane will also be parallel to the base-line, and its position may be obtained by a projection on a subsidiary vertical plane at right angles to the first.

Let TU (fig. 2 or 2 a) be the projection of the given zone-plane, and let the base-line X_1X_1' of the subsidiary vertical plane meet TU in T and XX' in O. Join Tp_1 and produce it to meet XX' in t_1. Then

$_1$ represents the distance from the horizontal plane of the intersection the given zone-plane with the original vertical plane. On X_1X_1' ake $Ot = Ot_1$, and draw tu parallel to XX', then tu is the projection of e given zone-plane on the vertical plane.

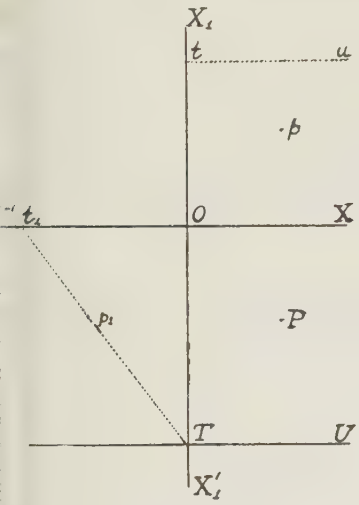

Fig. 2.

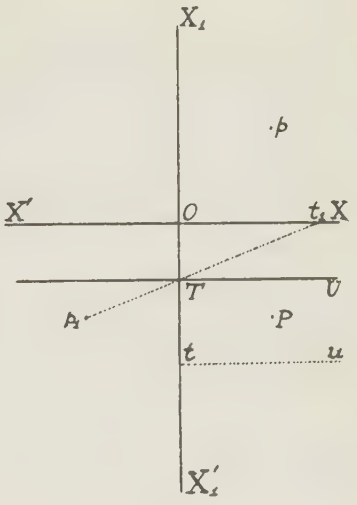

Fig. 2 *a*.

If the projection on the horizontal plane be parallel to the base-line l pass through P, the projection on the vertical plane will be entirely infinity, and vice versa, if the projection on the vertical plane pass rough p, that on the horizontal plane will be entirely at infinity.

(2) Given the projection of a face-normal on the horizontal plane, find the projection on the vertical plane.

This is solved by taking the projections of any two convenient zone- nes meeting in the face-normal and finding their projections on the tical plane. The point of intersection of these will be the projection he required face-normal.

(3) The projection of zone-planes and face-normals on an inclined ne may be found by taking a vertical plane at right angles to the izontal and inclined planes. The projections on the vertical plane first found and thence those on the inclined plane. If the inclined ne be at the same distance from the centre of projection as the izontal plane, it may be considered as a new horizontal plane obtained m the old horizontal plane by rotation about a horizontal axis through centre of projection.

(4) Given the projection of a zone-plane T_1U_1 on the horizontal plane, to find its projection on another plane obtained by rotating the first through an angle θ about a horizontal axis through the centre of projection.

Draw a vertical plane at right angles to the axis of rotation Cp, and let the base-line X_1X_1' meet T_1U_1 at U (fig. 3). Draw P_1Q_1 parallel, and Q_1R_1 at right angles to X_1X_1'. Then U_1t, parallel to R_1p, will be the projection of the zone-plane on the vertical plane. Draw the line pM_2 making an angle θ with P_1M_1p, and let $pM_2 = pM_1 =$ unity. Through M_2 draw X_2X_2' at right angles to pM_2, meeting pR_1 in R_2 and tU_1 in U_2. Draw Q_2R_2 at right angles to X_2X_2' and equal to unity. Then Q_2U_2 is the projection of the given zone-plane on the new horizontal plane.

For both the straight lines CQ_1 and CQ_2 pass through C and are parallel to pR_1; they are therefore the same straight line. Q_2 is therefore a point on the required projection on the new horizontal plane, and the same is the case with U_2.

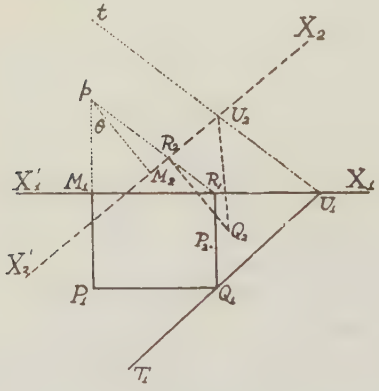

Fig. 3.

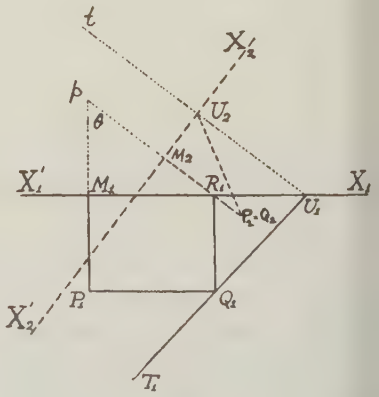

Fig. 3 a.

If the line pM_2 coincide with the line pR_1 the construction is somewhat simplified as shown by the accompanying diagram (fig. 3 a). The second horizontal plane will then be at right angles to the line CQ_1 and the point Q_2 will coincide with the point P_2, so that CP_2 is the line CQ_1 in a vertical position with regard to the new horizontal plane. P_2U_2 is therefore the projection required.

(5) The position of the projection of a face-normal after rotation may be obtained by considering it as the point of intersection of the pro-

jections of two convenient zone-planes, and finding the positions of these, and consequently of their intersection, on the second horizontal plane.

(6) To find the angle between any two face-normals whose projections are given.

The horizontal plane is rotated round the projection of the common zone-plane till it passes through the centre of projection and the face-normals. The true angle between these will then be obtained. This is, in fact, the usual construction. Let U and U' (fig. 4) be the projections of the face-normals. Then C_2U and C_2U' are the positions of the face-normals in the horizontal plane after rotation, and the angle UC_2U' is the true angle between them.

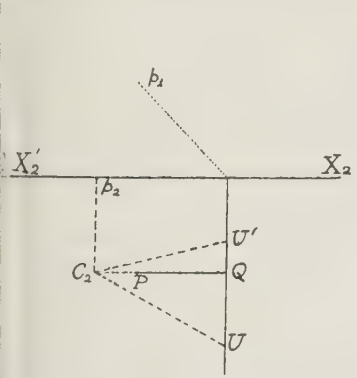

Fig. 4.

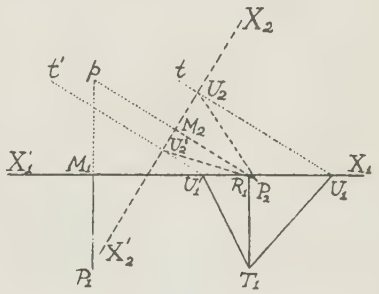

Fig. 5.

(7) Given the projection of a face-normal and a zone to which it belongs, to find the projection of another face-normal in the zone making a given angle with the first.

This is solved on the same principles as the previous problem.

(8) To find the angle between any two zone-planes whose projections are given.

Let the projections of the zone-planes be T_1U_1 and T_1U_1' (fig. 5) intersecting in T_1, the projection of their common face-normal. Assume a vertical plane with a base-line X_1X_1' parallel to the line P_1T_1, and intersecting the projections of the given zone-planes in U_1 and U_1'. Draw T_1R_1 at right angles to X_1X_1' intersecting it at R_1. Then U_1t and $U_1't'$, parallel to R_1p, will be the projections of the given zone-axes on the vertical plane.

Rotate the horizontal plane about Cp (the straight line through the

centre of projection at right angles to the vertical plane) through the angle M_1pR_1 so that it may take up a position at right angles to the line CT_1. The new base-line will then be the line $X_2M_2X_2'$ drawn at right angles to pR_1 at unit distance pM_2 from p. Let it intersect U_1t and $U_1't'$ in U_2 and U_2'. In pR_1 make M_2P_2 equal to unity.

Then CP_2 is the same straight line as CT_1, and P_2U_2 and P_2U_2' are the projections of the given zone-planes on the new horizontal plane. They are therefore lines in which those zone-planes meet a plane at right angles to their line of intersection, and the plane angle between them is the angle between the zone-planes.

(9) Given the projection of a zone-plane and that of a face-normal in it, to find the projection of another zone-plane including this face-normal and making a given angle with the first zone-plane.

This is solved on the same principle as the last problem. The horizontal plane is tilted till it is at right angles to the common face-normal. The projection of the required zone-plane is drawn at the given angle, and the horizontal plane rotated back to its first position.

(10) By the help of these constructions it is possible to solve spherical triangles where two sides and the included angle are given, or two angles and the included side, or two sides and the angle opposite one of them. The sides are represented by zone-planes and the angular points by face-normals.

In the last case the face-normal corresponding to the given angle is brought into the position CP and the projections of the two adjoining sides are drawn. On the projection of the adjoining side whose dimensions are given a corresponding length[1] is measured off (No. 7), and in this way the position of the face-normal is obtained which corresponds to the angle between the two sides whose dimensions are given. This face-normal is now brought into the position CP and a circle described round its projection at a distance representing the length of the side opposite the known angle. The intersections of this circle with the projection of the side of unknown length give the two spherical triangles satisfying the required conditions.

(11) Given the projection of a face-normal, to find the locus of the projections of face-normals making a given angle with it.

Let T_1 (fig. 6) be the projection of the given face-normal. Rotate the horizontal plane so as to bring the face-normal CT_1 into a vertical position CP_2. Draw a circle round P_2 as centre at a distance corre-

[1] Which would be equal in this position to the tangent of the circular measure of the side.

sponding to the angle θ, and let D_2 and D_2' be the extremities of the diameter parallel to X_2X_2'. Find the projections D_1 and D_1' on the original horizontal plane of the face-normals of which D_2 and D_2' are the projections on the second horizontal plane, then D_1D_1' is the major axis of the ellipse that forms the required locus and E_1 is its centre. Two other points K_1 and K_1' on the ellipse can be found on the line through T_1 at right angles to P_1T_1 by the method of (7), and from these data the ellipse can easily be constructed by the help of the auxiliary circle $D_1N_1M_1D_1'$.[1]

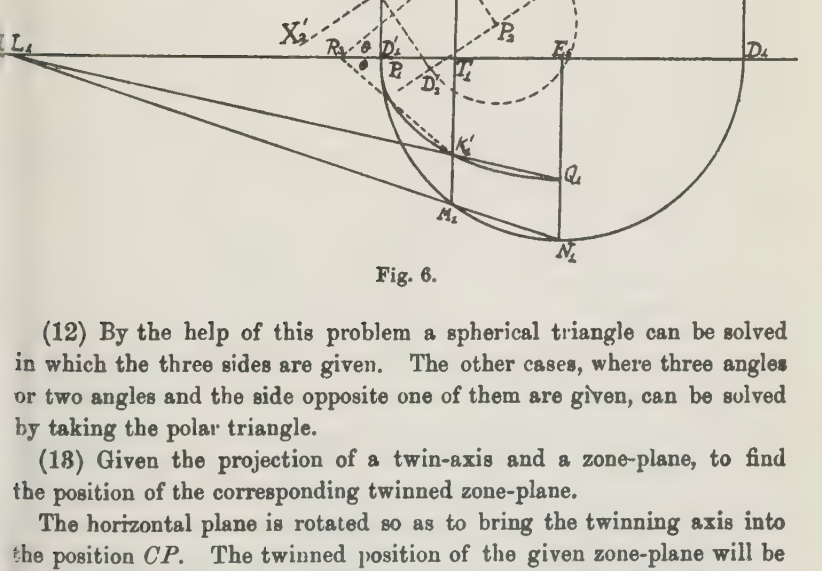

Fig. 6.

(12) By the help of this problem a spherical triangle can be solved in which the three sides are given. The other cases, where three angles or two angles and the side opposite one of them are given, can be solved by taking the polar triangle.

(13) Given the projection of a twin-axis and a zone-plane, to find the position of the corresponding twinned zone-plane.

The horizontal plane is rotated so as to bring the twinning axis into the position CP. The twinned position of the given zone-plane will be the parallel line on the opposite side of and at an equal distance from P. The horizontal plane can then be rotated back to its original position and the projection of the twinned zone-plane found in the usual manner.

[1] Let N_1 be any point on the circle, and M_1 the point on the circle where $K_1'T_1$ (produced) intersects it. Draw N_1M_1 meeting D_1D_1' in L_1. Draw L_1K_1' meeting at Q_1 the perpendicular from N_1 on D_1D_1'; then Q_1 is a point on the ellipse. In the diagram (fig. 6) Q_1 is the extremity of the minor axis of the ellipse.

(14) Given the projection of a twin-axis and that of a face-normal, to find the projection of the normal of the twinned face.

This can be done by taking two convenient zone-planes intersecting in the face-normal and determining their corresponding twinned zone-planes. The intersection of these projections will give that of the twinned face-normal.

All these constructions will apply to *linear projection*, if for zone-planes and face-normals there are substituted planes and lines parallel to the faces and edges of the crystal and passing through the centre of projection. The planes and lines of the linear projection are in fact the polar representatives of the face-normals and zone-planes of the gnomonic projection of the same crystal.

Both linear and gnomonic projection are of great convenience in the drawing of crystals, as they give at once the direction of the edges of the crystal in an orthogonal projection on the horizontal plane. In the gnomonic projection these are given by the lines drawn from P at right angles to the projection of the zone-plane: in the linear projection, by the lines joining P to the points representing the crystal-edges.

By rotating the horizontal plane through a convenient angle about any convenient axis it is easy to get a projection from which a drawing of the crystal may be obtained in a position which is adapted for showing its shape and symmetry.

In some cases there are other graphic solutions which involve fewer lines than those I have given in this paper, but the rationale is often not very obvious except to the expert mathematician, and to most mineralogists and students they will not afford so much insight into the spacial relations of the faces and zones of a crystal. In actual practice, too, some of the lines shown in the diagrams illustrating this paper may be omitted, and by judicious procedure the same lines are available for several different constructions. When two or three zones have been dealt with, the remainder can be worked out from them with only occasional resort to three dimensional methods.

I am indebted to Mr. T. W. Tyrrell for carefully executing the drawings illustrating this paper.

Determination of the optic axial angle of biaxial crystals in parallel polarized light.

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[Read November 14, 1905.]

IT will in the first place be assumed for the sake of simplicity that the crystal to be investigated is immersed in a liquid having a refractive index as nearly as possible equal to the intermediate refractive index (β), so that light travelling along the optic axis [1] is not appreciably refracted on entering or leaving the crystal.

The observation is made in parallel light between crossed nicols, which are rotated together till a position of extinction is reached, when the directions of vibration of the nicols will be parallel to those in the crystal. If the latter be now rotated on an axis parallel to one of these directions, it will in general show light throughout the revolution, except in the original position and that opposite to it. Occasionally, however, it will remain dark throughout; in that case the axis of rotation is the bisectrix of an optic axial angle. Sometimes, on the other hand, it will remain dark except in four positions opposite to each other in pairs; the axis of rotation is then the optic normal, and the plane in which the rotation takes place the optic axial plane. The four positions correspond to the two optic axes; and a determination of the angles between these positions would give the acute and obtuse optic axial angles, but the observation is not a very satisfactory one.

If the crystal be now returned to its original position, and the nicols rotated through 45°, the crystal will become light. With the nicols in this position it is easy to ascertain by means of a gypsum-plate or quartz-wedge whether the axis of rotation be parallel to the vibrations of the slow or fast wave-surface, in other words, whether it be positive or negative.

If the crystal be now rotated as before, it will, if the axis of rotation be either a bisectrix or optic normal, remain light through the entire revolution; but, if the sign of the axis of rotation be observed, a differ-

[1] Or, to use more accurate language, light whose wave-surface is at right angles to the binormal.

ence will be noted in the two cases. If the axis of rotation be a bisectrix the sign of the axis of rotation will remain the same throughout, and though the relative retardation between the two wave-surfaces will vary from point to point, it will never be zero. If, on the other hand, the axis of rotation be the optic normal, its optical sign will change four times during a revolution at positions corresponding to the optic axes; and at these positions the relative retardation will be zero.

The angles between these positions are the optic axial angles, and the sign of the axis of rotation in the interval between any two optic axes is the same as that of the bisectrix of the angle between them.

The exact points where the relative retardation is zero may be determined by inserting either a gypsum-plate showing a sensitive tint—preferably the red of the first order—or a double quartz-wedge such as is described on p. 91 of the present volume. The wedge should be placed in the focus of the eye-piece. If the plate be used, the position of an optic axis is marked by the appearance of the characteristic tint, while in the case of the wedge it is indicated by the exact coincidence of the bands on the two sides of the wedge. If the light used be strictly parallel, the quartz-wedge will give results equal, if not superior, to those given by the methods in which convergent light is employed. For the most accurate work mono-chromatic light should, I need not say, be used.

If the crystal substance is not immersed in a liquid of the required refractive index, it should have one or more pairs of parallel plane surfaces, and the refractive index between it and the medium in which it lies should be such as to allow of the emergence of two optic axes whose apparent positions may be determined in the manner described above. Thence their true positions and the angle between them may be calculated in the usual manner.

The principal advantage of the method described in this paper is that it can be employed in the case of minerals occurring in a thin section of a rock. In strongly convergent light this can only be turned through a comparatively small angle, but in parallel light under a low power it can be rotated to any required extent.

It is preferable to employ a microscope in which both nicols revolve together. With it should be used a stage-goniometer or 'Universal Drehapparat[1],' which allows of two rotations, one about an axis at right angles to the axis of the microscope, and the second about an axis at

[1] The 'Universal-Drehapparat' designed by C. Klein is well suited for use with this method; see H. Rosenbusch, 'Mikroskopische Physiographie der Mineralien und Gesteine,' vol. i, part 1, 4th edition, by E. A. Wülfing, 1904, pp. 204–205.

right angles to that of the first as well as to the plane of the glass slip supporting the thin section. It should be fitted with an arrangement for holding the glass slip, so that any desired portion of the section may be retained at the centre of rotation. The glass slip should be of less than the usual size. Though not absolutely necessary, it is very desirable to employ some form which allows of immersion in liquid. Instruments in which glass hemispheres are employed instead of immersion are unsuitable, as these interfere with the parallelism of the light.

The rock slide must be searched to find a crystal cut at right angles to the optic axial plane and which allows the emergence of two optic axes in the medium employed. This search may be carried out in parallel light by looking for a section which gives, on rotation about the axis at right angles to the axis of the microscope, the phenomena described above as characteristic of a rotation on the optic normal; but it will usually be more convenient in the first place to use convergent light, when the symmetrical 'pendulum movement' of the dark brush or 'isogyre', will, as F. Becke [1] has shown, indicate a section cut at right angles to the optic axial plane, and thus one suitable for further examination in parallel light for finding the positions of emergence of the optic axes.

In conclusion, I have only to add that it is to E. S. Fedorov [2] that we owe the principle of the examination of the optical characters of a crystal by rotation in different directions in parallel polarized light, of which principle the method described in this paper is only a special development.

[1] F. Becke, 'Die Skiodromen,' Min. petr. Mitt. (Tschermak), 1905, vol. xxiv, pp. 1–34.

[2] Zeits. Kryst. Min., 1893, vol. xxii, p. 229; 1896, xxvi, p 225; 1896, xxvii, p. 337; 1898, xxix, p. 604.

Geikielite and the ferro-magnesian Titanates.

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Assistants in the Scientific and Technical Department of the Imperial Institute.

[Read January 23, 1906.
Communicated by permission of the Director of the Imperial Institute.]

IN connexion with the systematic examination of the minerals of Ceylon, which is being conducted in the Scientific and Technical Department of the Imperial Institute, the authors have recently examined a large quantity of coarse gem-gravel refuse obtained from the Balangoda and Rakwana districts of Ceylon.

The material varies somewhat in character, but zircon generally predominates, while tourmaline, corundum, and pleonaste are fairly abundant. Among other minerals present in noticeable quantities are geikielite, picroilmenite, ordinary ilmenite, rutile, and fergusonite, all of which are generally in the form of rounded or sub-angular pebbles.

This association of the members of the geikielite-ilmenite series seemed to be a matter of some interest, especially on account of the fact that among the specimens examined there occurred varieties having specific gravities intermediate between those of geikielite and picroilmenite.

Geikielite.

Physical characters.—The specimens identified as geikielite are quite similar in their physical characters to those first described by Mr. Allan Dick.[1] They have a dull black appearance on worn surfaces, but freshly fractured surfaces are jet-black and show a somewhat vitreous lustre. The cleavage is rhombohedral, the angles between the cleavage-planes being about 93½°. This appears to be a true cleavage and not a parting. None of the specimens shows any trace of twinning. The cleavage-faces when perfectly fresh show a metallic-adamantine lustre, but generally they are dulled by a thin film of titanium dioxide, even in the freshest specimens. It is only when this film is present that the plum-coloured hue described by Mr. Dick can be seen. The fracture is generally uneven, but occasionally sub-conchoidal. The hardness is 6.

The streak is purplish-brown, and not black as stated by P. von

[1] Min. Mag., 1893, vol. x, p. 145.

Sustschinsky.[1] When the powder is finely ground in an agate mortar, its colour is deep purple and quite characteristic. The mineral is opaque, except in thin splinters under the microscope, these being translucent and of a deep reddish-purple colour. The splinters give a uniaxial figure of negative sign, and are non-pleochroic. Geikielite is slightly magnetic, but less so than picroilmenite and much less so than common ilmenite.

Chemical composition.—In the analysis published by Dick, only 3·8 per cent. of iron oxide was recorded. In 1902, Sustschinsky, who examined some geikielite from Ceylon having the same physical characters as that described by Dick, recorded 9 per cent. of iron oxide. The following are the two analyses:—

	Dick.	Sustschinsky.
TiO_2	67·74	61·32
FeO	3·81	2·03
Fe_2O_3	—	7·75
MgO	28·73	28·95
	100·28	100·05
Specific gravity ...	3·98–4·0	3·976

The results of a considerable number of analyses of the material examined by the present authors confirm the analysis recorded by Sustchinsky. The following are two typical analyses of geikielite poor in iron:—

	I.	Molecular ratios.	II.	Molecular ratios.
TiO_2	64·78	... 0·809	... 64·41	... 0·805
FeO	5·92	} 0·110[2]	... 5·44	} 0·114[2]
Fe_2O_3	2·22	... }	... 2·77	... }
MgO	27·90	... 0·697	... 27·90	... 0·697
	100·82		100·52	
Specific gravity ...	3·89	...	... 3·97	

The specimen used for analysis I is slightly altered and shows leucoxene along the cleavage-cracks; hence the comparatively low specific gravity. The material II was quite fresh, and the specific gravity given

[1] 'Beiträge zur Kenntniss des Geikielith, Ilmenit und Hämatit,' Zeits. Kryst. Min., 1902, vol. xxxvii, p. 57; abstract Min. Mag., vol. xiii, p. 307.

[2] All the iron is calculated as ferrous oxide.

above may be taken as representing the true value for unaltered geikielite containing 8·2 per cent. of iron oxide.

It seemed unlikely that these specimens could differ chemically from those examined by Mr. Dick, seeing that they were so very similar in all other respects. Accordingly, Mr. Dick kindly permitted his material to be re-examined. The fragments consisted partly of rutile, but this was coarse enough to allow of its separation. A portion of geikielite free from rutile gave the following analysis:—

	III.
TiO_2	63·77
FeO	6·34
Fe_2O_3	1·93
MgO	28·50
	100·54

From this result it seems probable that the iron oxide was not completely separated from the titanium dioxide in the original analysis.

The method of analysis adopted was fusion of 0·3 to 0·5 gram of the finely powdered mineral with potassium hydrogen sulphate, the solidified cake being dissolved in cold water acidified with sulphuric acid. After diluting to one litre and reducing with a little sodium sulphite, the whole was boiled from six to seven hours, water being added at intervals to replace that lost by evaporation. The precipitated titanium dioxide was filtered off, dried, ignited with a few grains of ammonium carbonate, and weighed. The titanium dioxide thus obtained generally contained about 2 per cent. of iron oxide, and sometimes as much as 7 per cent.; but it rarely contained more than a trace of magnesia. The process of fusion was repeated to separate completely the iron oxide and magnesia. A third fusion was necessary in two cases only. The filtrate from the titanium dioxide was tested with hydrogen peroxide to make sure that all the former was precipitated; then ammonium chloride was added, and the total iron and magnesium determined in the usual way. To determine the ferrous iron, a portion of the powdered mineral weighing about 0·3 gram was decomposed by a mixture of hydrofluoric and dilute sulphuric acids, in the absence of air, and the solution obtained titrated with potassium permanganate.

Geikielite with only 8 per cent. of iron oxide is comparatively rare in the gem-gravels. More commonly, varieties occur which are somewhat richer in iron, containing 10 to 14 per cent. of the oxides. These have a somewhat higher specific gravity, as one would expect. They also

diminish somewhat in transparency, while the streak and colour of the powder deepen in shade as the percentage of iron increases. The following analyses illustrate the varying composition of these specimens:—

	IV.	V.[1]	VI.	VII.	VIII.	IX.	X.
TiO_2 ...	63·94	64·03	62·49	62·25	61·60	60·87	60·02
FeO ...	10·09	12·14	10·70	11·58	7·79	6·03	5·81
Fe_2O_3 ...	0·25	—	3·54	—	4·95	5·69	6·80
MgO ...	25·79	24·66	23·60	26·03	26·31	27·29	27·79
	100·07	100·83	100·33	99·86	100·65	99·88	100·42
Sp. gr.	4·01	4·11	4·01	3·91	3·90	3·87	3·79

The material of analyses IV and V was fresh; that of VI slightly decomposed along the cleavages; while in VII, VIII, IX and X it showed growths of leucoxene increasing in amount as the specific gravity diminishes.

From these results it is seen that ferric iron may or may not be present, but ferrous iron is always present, and generally in much larger quantity than the ferric. Further, the ferric oxide appears to be sometimes of primary and sometimes of secondary origin. In some instances (as in Nos. VIII, IX, and X) the ferrous iron and magnesia unite with the titanium dioxide, leaving a surplus of ferric oxide. When this is the case, it seems reasonable to explain the presence of ferric oxide as an isomorphous replacement of the geikielite molecule. In other cases, however (as in Nos. I, II, IV, and VI), there is a deficit in the sum of ferrous oxide and magnesia molecules, a deficit which is remedied by reducing (in calculation) such ferric oxide as is present to a ferrous state, and adding this to the sum of existing ferrous oxide and magnesia. In these cases it appears probable that the ferric oxide is secondary and that it has arisen by oxidation from the ferrous state. In still other cases both primary and secondary ferric oxide appear to be present. It is only on this assumption that many of the analytical results can be explained.

It is, however, a noteworthy fact that a specimen may show a considerable amount of the leucoxene decomposition product, though containing no secondary ferric oxide; on the other hand, apparently fresh specimens may contain this secondary ferric oxide.

[1] No. V contained a trace of manganese.

In general, the *specific gravity* increases with the percentage of iron, but within narrow limits the variations are complex and difficult to understand, though the reduction of the specific gravity by the partial decomposition along the cleavages accounts for most peculiarities. Assuming equal molecular volumes for the different members of the geikielite-ilmenite series, and taking the specific gravity of ilmenite ($FeTiO_3$) as 4·7, the specific gravity of geikielite free from iron ($MgTiO_3$) should be 3·7. In this connexion the following comparison is of interest as illustrating the relation between specific gravity and composition in some of the least altered specimens:—

	Calculated sp. gr.	Observed sp. gr.
$(Mg,Fe)TiO_3$ with 8 per cent. FeO	3·87 ...	3·97
„ „ 14 „ „	3·96 ...	4·11
„ „ 27 „ „	4·28 ...	4·30
„ „ 34 „ „	4·42 ...	4·44

It is probable that neither the calculated nor the observed specific gravities are correct in the second place of decimals, as the specific gravity of ilmenite is uncertain and the specimens are liable to decomposition. But such as the numbers are, they appear to indicate that the molecular volume for the geikielites is somewhat smaller than that for the ilmenites.

Alteration products of geikielite.

Rutile.—The specimens are generally free from visible intergrowths with other minerals. One specimen, however, is associated with rutile as an alteration product. It is sub-angular in shape and weighed about 16 grams; it appears to have been broken from a much larger specimen. Except on the fractured surface, which has the characteristic thin film of titanium dioxide, the specimen is covered with a shell of rutile varying in thickness from one to two millimetres. The surface of contact between the geikielite and the rutile is very irregular, and there can be no doubt that the latter has resulted from the alteration of the former. The specimen is quite free from intergrowth, and the rutile is confined to the external surface.

Leucoxene.—This is white or yellowish-white in colour, opaque, and for the most part apparently amorphous. It is the commonest alteration product of geikielite and is similar in appearance to that familiar on the cleavage-planes of ilmenite. It is generally confined to the cleavage-planes; one specimen was found, however, a portion of which was almost

completely decomposed, and this furnished about a decigram of material which gave the following analysis:—

TiO_2	81·3
Fe_2O_3	6·4
CaO	3·0
MgO	trace
SiO_2	4·2
H_2O	5·6
	100·5

In this case the leucoxene consists mainly of amorphous titanium dioxide. The ferric oxide is probably present as limonite, while the lime and silica are probably in combination with a portion of the titanium dioxide as sphene.

Sphene.—This occurs as colourless, translucent granules intimately associated with the leucoxene in the cleavage-cracks. These granules show the optical characters of sphene, and their identification as such is confirmed by the above analysis of the leucoxene.

Limonite.—This was observed in the cavities of much decomposed specimens.

Picroilmenite.

Picroilmenite[1], or magnesian ilmenite, appears to occur in considerable quantities in the Balangoda district. It has a specific gravity of 4·25, when fresh; two specimens gave the following analyses:—

	XI.	XII.
TiO_2...	57·64	56·08
FeO	16·57	24·40
Fe_2O_3	10·17	5·43
MgO...	15·56	14·18
	99·94	100·09
Specific gravity ...	4·17	4·25

In specimen No. XI, the ferric oxide appears to be partly primary and partly secondary, while in No. XII it is all primary. The mineral is thus very similar in composition to the magnesian ilmenite of

[1] P. Groth, 'Tabell. Übers. d. Mineralien,' 4th edition, 1898, p. 143.

Warwick, New York, analysed by C. F. Rammelsberg in 1858, and by S. L. Penfield and H. W. Foote[1] in 1897.

Notwithstanding its high percentage of iron, it is translucent in very thin splinters under the microscope and shows a deep purple-red colour very similar to that of geikielite. Its streak, and the colour of its powder in the mass, are similar to those of geikielite in tint, but much darker in shade. Its hardness is 6, and, like geikielite, it appears to be about half a degree, on Mohs's scale, harder than ilmenite.

In all its properties it is much more akin to geikielite than to common ilmenite. Its composition generally corresponds to the formula $(Fe,Mg)TiO_3$, where $Fe : Mg = 1 : 1$; this fact, together with the intermediate character of its general properties, makes it advisable to regard picroilmenite as the middle member of the series of ferro-magnesian titanates. Those members of the series containing less magnesia and more iron oxide than picroilmenite should be classed as ilmenites, while those with more magnesia and less iron should be classed as geikielites.

Summary and Conclusions.

1. Up to the present no geikielite has been found containing less than 8 per cent. of iron oxide.

2. For this reason the formula $(Mg,Fe)TiO_3$ represents the composition of geikielite more correctly than the formula $MgTiO_3$.

3. Picroilmenite is closely related to geikielite in its general properties.

4. It is advisable to divide the ferro-magnesian titanates into ilmenites and geikielites, and to regard picroilmenite as the middle member of the series.

5. It seems likely that, considering the association in the present instance of geikielite and picroilmenite, many specimens commonly classed with the latter may turn out on closer examination to be geikielite.

6. The alteration products of geikielite are similar to those of ilmenite, and include rutile, amorphous titanium dioxide (leucoxene), sphene, and limonite.

[1] Amer. Journ. Sci., 1897, ser. 4, vol. iv, p. 108.

Dundasite from North Wales.

By G. T. Prior, M.A., D.Sc., F.G.S.

Assistant in the Mineral Department of the British Museum.

[Read March 15, 1905.]

THE mineral dundasite was first described by W. F. Petterd in 1893, in a 'Catalogue of Minerals known to occur in Tasmania'[1]. It was found in small, silky, milk-white, spherical aggregates incrusting a 'ferro-manganese gossan' at the Adelaide Proprietary mine, Dundas. In this catalogue, and in a subsequent one dated 1896, it was stated, as the result of qualitative tests, to be a hydrated carbono-phosphate of lead and aluminium; but a quantitative analysis (see below under II), made later by S. Pascoe, showed that the mineral is a hydrated carbonate of lead and aluminium, and that the traces of phosphoric acid were due to a thin coating of pyromorphite. In this analysis the water and carbonic acid were determined together, by loss on ignition, and consequently hitherto no chemical formula has been attributed to the mineral. In his 'Notes on unrecorded and other minerals occurring in Tasmania'[2], in which this analysis appears, Mr. Petterd mentions another locality for dundasite in Tasmania—viz. the Hercules mine, Mt. Read, where it was found in patches on a mass of cellular quartz through which were scattered crystals of cerussite and gibbsite.

At a recent meeting of the Mineralogical Society, Mr. H. F. Collins showed me specimens of a mineral which had been found[3] in small, silky, white tufts upon cerussite in the 23 ft. level, Francis lode, Welsh Foxdale mine, near Trefriw, Carnarvonshire. These specimens he kindly placed at my disposal for determination.

Chemical analysis showed that the mineral must be referred to dundasite. In physical characters it is precisely similar to the Tasmanian mineral, of which a specimen, obtained from Mr. Petterd, is in the British Museum collection. It occurs in small (mostly not more than 1 mm. in diameter), white, spherical aggregates or tufts consisting of a felted mass of minute,

[1] Papers and Proceedings of the Royal Society of Tasmania, for 1893, 1894, p. 26.
[2] Papers and Proceedings of the Royal Society of Tasmania, for 1902, 1903, p. 22.
[3] To Mr. G. J. Williams, H.M. Inspector of Mines, appears to be due the credit of having first noticed these tufts of a mineral unknown to him on some cerussite specimens from the Welsh Foxdale mine.

radiating, silky needles. Under the microscope these needles are seen to be fairly strongly refractive (equal to mono-bromo-naphthalene, 1·66) and doubly refractive (some of the larger needles show yellow and red of the first order), to give straight extinction, and to compensate across their length with a quartz-wedge cut parallel to the optic axis : no definite optic axial figure was observable through them in convergent light.

In the specimens presented to the British Museum by Mr. Collins, the tufts of dundasite are associated with beautiful, small, glassy spherules, which analysis showed to be allophane ; and both these minerals were thickly distributed in the interstices of a mass of loosely cohering, long-prismatic crystals of cerussite.

The material for analysis was obtained by picking out spherules from a quantity of débris, derived apparently from the breaking up of various specimens. Most of these spherules were tinged slightly yellow from impurity of oxide of iron, but otherwise they appeared to be fairly pure and free from cerussite. The result of the analysis is given under I, as compared with that of dundasite from Tasmania under II, while under III is given the theoretical composition corresponding to the formula, $PbH_2(CO_3)_2.Al_2(OH)_6$.

	I. (N. Wales).	Molecular ratios.	II. (Tasmania).	III. $PbH_2(CO_3)_2.Al_2(OH)_6$.
PbO	43·20	0·1938	41·86	45·95
Al_2O_3	21·39	0·2093	26·06	21·07
Fe_2O_3	1·61	—	5·50	—
CO_2	16·45	0·3739	} 28·08	18·14
H_2O (above 100°)	13·60	0·7556		} 14·84
H_2O (at 100°)	1·41	—		
Insoluble	1·80	—		—
	99·46		101·50	100·00

Weight of material used in analysis 0·2140 gram. The water was determined by Penfield's bulb-tube method, and the carbonic acid was estimated by difference between the water and the total loss on ignition. The density of the mineral was determined, by immersing in methylene iodide diluted with benzol, to be between that of axinite and apatite, i. e. about 3·25. That of dundasite from Tasmania was found to be practically the same. The numbers obtained in the analysis suggest the formula $PbO.Al_2O_3.2CO_2.4H_2O$ or $PbH_2(CO_3)_2.Al_2(OH)_6$.

In physical characters and also in chemical composition the mineral

nows a close relationship to dawsonite, the hydrated carbonate of sodium nd aluminium, to which the formula $Na_2O.Al_2O_3.2CO_2.2H_2O$ has been ttributed.

Characters of dundasite :—

Occurs in white, spherical aggregates or tufts of minute, radiating eedles. Hardness, 2. Density, 3·25. Lustre, vitreous. Colour, white. ransparent. Refraction and double refraction, fairly strong: needles give raight extinction and are positive. Chemical formula,

$$PbO.Al_2O_3.2CO_2.4H_2O.$$

Paratacamite, a new oxychloride of copper.

By G. F. Herbert Smith, M.A., F.G.S.

With a chemical analysis by G. T. Prior, M.A., D.Sc., F.G.S.

Assistants in the Mineral Department of the British Museum.

[Read March 15, 1905.]

ABOUT two years ago there was brought to the British Museum a specimen covered with numerous small cubes—so the crystals appeared to be—of the bluish-green colour suggestive of a mineral containing copper. Judged by their form the crystals might be boleite, but a qualitative analysis by Dr. Prior, while revealing the presence of chlorine and copper, showed no trace of lead. A crystal was then removed from the specimen and measured on a goniometer, and the discovery was at once made that these apparent cubes are in reality rhombohedra with an angle of nearly 88° between adjacent faces. Since no previously known oxychloride of copper crystallizes in this form, these crystals were evidently worthy of further investigation. Inquiry elicited the information that the specimen was one of between seven and eight hundred, mostly mineral, specimens which had been collected in Chili by a mining engineer, of the name A. Anabalón y Uryúa; the manuscript catalogue of the collection is dated September 1899. The collection ultimately came into the hands of Mr. F. H. Butler, of London, and, his attention having been directed to these curious crystals, he brought the specimen to the Museum. As it was desirable to accumulate as much material as possible for a complete examination of the properties of this new mineral, all those specimens in the collection which showed any green crystals were examined. Many turned out to be atacamite; but other specimens were found which displayed crystals of the new mineral, all of which were acquired by the Trustees of the British Museum, with the exception of two, which had previously been purchased by Mr. Arthur Russell, who with ready courtesy, which the author gladly acknowledges, lent them for the purposes of this investigation. Altogether ten specimens of the new mineral were discovered, but the crystals employed in the determination of the morphological characters were taken from the best of them, four in number.

The Herminia mine and the Generosa mine, Sierra Gorda, Chili, are the localities given on the labels for nine of the specimens; the remaining specimen, which exhibits a few minute crystals of the new mineral in conjunction with native gold, comes from the Bolaco mine, San Cristóbal, Chili. The matrices are more or less decomposed, and one specimen in

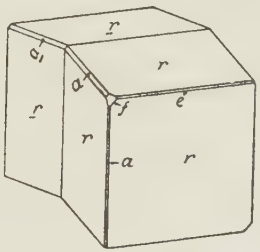


Fig. 1.

Paratacamite. Twinned crystal: Rhombohedral type.

particular is almost falling to pieces. In addition to quartz the associated minerals are galena and caracolite, both of which are much altered. The former has in places disappeared altogether, leaving a reticular arrangement of small square pits; the latter has no doubt been in part affected by the cleansing which the specimens had undergone before reaching the Museum, in order to rid them of the mud and dirt encasing them.

The types of crystals are two in number. In one, as has already been stated, the crystals resemble cubes but are really rhombohedra. Certain edges and corners are often truncated by small faces. Fig. 1 depicts such a rhombohedron twinned about one of its faces; similar crystals are very common. Crystals of the second type differ markedly in appearance from those of the first, and may easily, at a glance, be mistaken for atacamite. They are prismatic in form, being elongated parallel to the edge of a zone [*rfa*], and, since they are invariably twinned about the face of the form *r* lying in this prismatic zone, they simulate orthorhombic symmetry. Crystals of this kind are shown in figs. 2 and 3; the second individuals, which lie at the back and cannot be seen, are in every way similar to the first. When there are no re-entrant angles—and this is frequently the case—nothing suggests on ordinary inspection that these crystals are really twinned. The angles *rr* and *rc* are respectively 52° 55′ and 49° 48′; in the case of a crystal of atacamite, for which it might be mistaken, the angles *bm* and *be* are

56° 31½′ and 53° 1½′[1]. The difference of a few degrees in the case o the corresponding angles is too small to be detected by the unaided eye Crystals of atacamite, however, from this district usually show the form

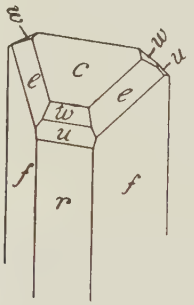


Fig. 2.

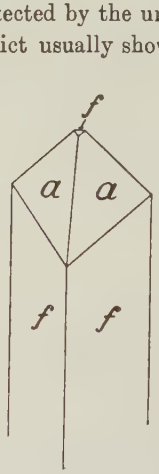


Fig. 3.

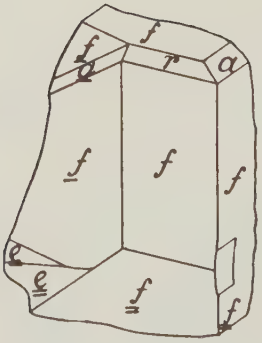


Fig. 4.

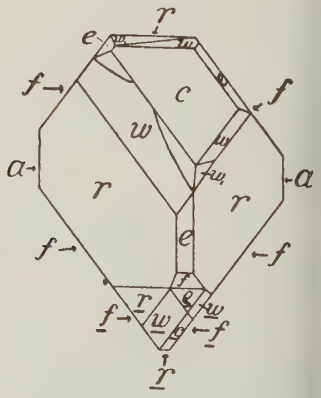


Fig. 5.

Paratacamite. Twinned crystals: Prismatic type.

h (132), which is invariably striated parallel to its intersection with *e* (011), and this form, if present, serves to discriminate the two minerals since no form similarly striated is displayed by the new mineral.

There is a good cleavage parallel to the principal rhombohedron

[1] These angles are taken from the author's paper, Min. Mag., 1898, vol. xii pp. 15-25.

face *r*. Twins with respect to the same face are very common; indeed the prismatic type seems to be invariably twinned. Various types of twin-crystals are illustrated in figs. 1–5. The crystal drawn in fig. 4 is remarkable for the conjunction of three distinct individuals, the faces of which are denoted by letters with no bar, one bar, and two bars underneath respectively. The three contiguous faces of the form *f* are parallel and give on the goniometer a single image. The first and second individuals are related by the ordinary twinning about a face *r*. The first and third are in parallel positions, and possibly the latter may have arisen from independent twinning with respect to the second individual. Another plausible explanation is that a face of the form *a* is the twin-plane, although such a twin has not been otherwise observed. It may be remarked that the line of demarcation between the first and third individuals is parallel to the edge of a zone [*rfa*]. The crystal illustrated in fig. 5 is noteworthy for the vicinal planes accompanying the faces of the form *w*. In two cases it is quite a distinct face (lettered w_1), while in the third it gives an irregular intersection with the corresponding face *w*. The measurements from *c* of the three faces w_1, on this particular crystal relative to the corresponding face *w*, are as follows:—

	Azimuth.	Distance.
w_1	2°20′	29°16′
	0 59	29 15
	2 24	28 17
w	0 0	25 20

and the calculated values for a face of the form (411) are

(411)	0 0	30 37

Thus w_1 lies near the form (411), but so variable is its position on the various crystals measured that no definite symbols can be assigned to it. Its distance from the corresponding face *w* is fairly constant, greater variation occurring in the orientation.

The crystals are mostly small in size, rarely exceeding 2 mm. in any direction; often they are merely needles, less than 1 mm. in length and 0·5 mm. in cross-section.

The name paratacamite has been assigned to the new mineral, because, as the analysis given below shows, the percentage chemical composition is the same as that of atacamite. A certain connexion can be traced between the measurements on crystals of the two minerals made from the respective cleavage-faces, as appears from the following table:—

TABLE I.

Comparison between the Measurements on Paratacamite and Atacamite.

Paratacamite. Measured from *r* (100).			Atacamite.[1] Measured from *b* (010).		
Form.	Azimuth.	Distance.	Form.	Azimuth.	Distance.
a 0$\bar{1}$1	90° 0′	90° 0′	*c* 001	90° 0′	90° 0′
f 1$\bar{1}$1	„ „	52 55	*e* 011	„ „	53 1½
r 001	41 49	82 49½	*u* 101	41 17½	90 0
e 101	„ „	41 25	*r* 121	„ „	45 11
a 10$\bar{1}$	„ „	−48 35			
e 011	0 0	80 25	*a* 100	0 0	90 0
c 111	„ „	49 48	*m* 110	„ „	56 31½
f $\bar{1}$11	„ „	−63 6½			

Altogether forty-three crystals were measured on the three-circle form of goniometer[2] designed by the author, in every case the reference-pole being a face of the form *r*. In the case of six crystals, in which the face *c* is well developed, measurements were made from this face also, and on some crystals of the type illustrated in figs. 2 and 3 controlling measurements were made from faces of the form *f*.

The observed forms, nine in number, are as follows:—

Form.	Indices. Rhombohedral.	Indices. Hexagonal.	Characters, &c.
c	111	0001	Not always found: generally small, but occasionally large: images distinct.
r	100	10$\bar{1}$1	Occurs on every crystal: large in the rhombohedral type, the faces being distorted and the images consequently blurred, and small in the prismatic type, the images being distinct; a good cleavage parallel to faces of this form, twin-plane.
f	11$\bar{1}$	02$\bar{2}$1	Common: small, almost minute, on the rhombohedral type, and large on the prismatic type; images good.
e	110	01$\bar{1}$2	Common, but small: images distinct.
a	10$\bar{1}$	11$\bar{2}$0	Common: small and frequently much curved; in the latter case images are spread out and often lie an appreciable distance from the theoretical position.

[1] These values are taken from the author's paper, loc. cit.

[2] Min. Mag., 1899, vol. xii, pp. 175–182.

w	113	$0\bar{2}25$	Common, but small: often accompanied by vicinal planes: images poor.
v	229	0·7·7·13	Rare and minute: images very faint.
u	115	$0\bar{4}47$	Rare and minute: images poor.
l	313	$24\bar{6}1$	Rare and minute: images poor.

The terms used to indicate the size of the faces must, of course, be interpretated relatively to the size of the crystals.

In Table II are compared the calculated values and the means of the observed azimuths and distances corresponding to the various forms, *r* being the reference-pole; the angles employed as the basis for the calculations are indicated by the asterisks. In Table III are given the calculated values, *c* being the reference-pole, together with the mean angles observed on the six crystals measured from this pole.

Table II.

Measurements from $r = (100) = (10\bar{1}1)$.

Indices.		Calculated Values.		Observed Means.		Number.	Limits of Observations.	
Rhombohedral.	Hexagonal.	Azimuth.	Distance.	Azimuth.	Distance.		Azimuth.	Distance.
$01\bar{1}$	$\bar{1}2\bar{1}0$	*	*	90° 0′	90° 0′	26		90°20′
133	$26\bar{4}1$	,,	75°51½	,, ,,	75 56	5		75°42′–76 15
$11\bar{1}$	$02\bar{2}1$	,,	52 55	,, ,,	52 57	69		52 29–53 15
331	$64\bar{2}1$	60°48′	−47 47	61 10	−47 41	2	61 7′, 61°18′	47 36, 47 46
010	$\bar{1}101$	41 49	*	41 53½	82 49½	74	41 7–42 37	81 56–83 28
110	$01\bar{1}2$	,, ,,	41 25	,, ,,	41 24	37	,, ,, ,, ,,	41 8–41 51
$1\bar{1}0$	$2\bar{1}\bar{1}0$	,, ,,	−48 35	,, ,,	−48 27	33	,, ,, ,, ,,	48 5–48 56
151	$\bar{4}407$	30 49	71 17½	30 15	71 14	1		
131	$22\bar{0}5$	24 6	65 10	24 22	65 23	16	23 45–24 57	64 39–66 0
$33\bar{1}$	$62\bar{4}\bar{1}$	,, ,,	−52 20	,, ,,	−52 21	6	,, ,,–,, ,,	51 30–52 56
011	$\bar{1}012$	*	80 25	0 0	80 30½	18		80 9–80 56
111	0001	,,	49 48	,, ,,	49 45	29		49 6–50 10
311	$20\bar{2}5$	,,	24 28	,, ,,	23 59½	14		23 11–24 39
922	7.0.7.18	,,	17 7½	,, ,,	17 24	3		17 7–17 45
511	$40\bar{3}7$	,,	15 44	,, ,,	15 48	5		14 54–16 6
$1\bar{1}1$	$20\bar{2}1$	,,	−63 6½	,, ,,	−62 56½	41		62 25–63 41

TABLE III.

Measurements from $c = (111) = (0001)$.

Rhombohedral; axis $c = 1{\cdot}0248$.

Form.	Indices.		Calculated Values.		Observed Means.		Number.	Limits of Observation	
	Rhombohedral.	Hexagonal.	Azimuth.	Distance.	Azimuth.	Distance.		Azimuth.	Distan
a	$\bar{1}01$	$\bar{1}\bar{1}20$	30° 0′	90° 0′	30° 0′	90° 0′	2	30°23′	
l	313	$\bar{4}261$	19 6½	80 56	19 7	80 55	2	19° 0′, 19 14	80°50′,
f	$\bar{1}11$	2021	0 0	67 5½	0 0	67 12	24		66 30 –
e	011	$\bar{1}012$	,, ,,	30 37	,, ,,	30 41	17		29 45 –
w	311	2025	,, ,,	−25 20	,, ,,	−25 31	6		25 5 –
v	922	7.0.7.13	,, ,,	−32 40½	,, ,,	−32 42	6		32 15 –
u	511	4047	,, ,,	−34 4	,, ,,	−33 45	3		33 32 –
r	100	$10\bar{1}1$	,, ,,	−49 48	,, ,,	−49 42	17		49 0 –

Perhaps the most interesting point connected with these crystals is the fact that the optical characters displayed by them are not in accordance with the apparent morphological symmetry. Unless crushed to minute fragments they do not give extinction between crossed nicols, and there is no noticeable variation in the intensity of the transmitted light. A few crystals were crushed in oil, and occasional fragments were observed which are approximately perpendicular to one of the optic axes characterizing a biaxial crystal, and give in convergent light a biaxial brush. The precise relation of these microscopic fragments to the crystalline arrangement could not be ascertained, since it was not found possible to grind a section thin enough for the purpose.

As may be expected from what has just been stated, paratacamite is apparently singly refractive as far as regards light refracted across a prism. An approximate determination of the index gave the value 1·846 for the green light which is transmitted by the crystals; light of longer wave-length is almost entirely absorbed in transmission across the smallest crystal available for this purpose. The value obtained is very near the mean index of atacamite.[1]

[1] loc. cit., p. 24.

Chemical Composition (G. T. P.).

Chemical analysis shows that the mineral is an hydrated oxychloride of copper having the same empirical formula as atacamite, viz.

$$CuCl_2.3Cu(OH)_2.$$

An analysis made on 0·5132 gram gave the following result:—

CuO	56·10
Cu	14·27
Cl	15·97
H_2O [1]	14·10
	100·44

The density (weight of 1 cc.) of the mineral is 3·74, as determined with a 3 cc. pyknometer on 0·7430 gram.

In the case of the oxychlorides of lead, paralaurionite and laurionite, which are also two minerals having the same percentage chemical composition [2], it was found that the latter mineral on ignition began to lose water at a lower temperature than the former. Experiment suggests that a similar relation subsists between paratacamite and atacamite. On heating at gradually increasing temperature up to 230° C. no change was produced in either mineral; but, after heating for about an hour at 250°, 0·0976 gram of atacamite began to blacken and lost about 2 mg. in weight, while paratacamite (0·1027 gram) still remained unchanged; continuing the heating for another hour at 260°, however, paratacamite just began to blacken and lost 0·5 mg., while atacamite lost an additional 2 mg. After heating for another hour at 280°, atacamite had lost altogether 5 mg. and paratacamite 4 mg.

Summary of Characters.

An hydrated oxychloride of copper, $CuCl_2.3\,Cu(OH)_2$. Pseudo-rhombohedral. Twins common, twin-plane *r*. Commonly in rhombohedra (*r*), or slender prismatic crystals elongated parallel to the edge of a zone [*rfa*]. Cleavage, *r* good. Fracture, conchoidal. Brittle. H. = 3, G. = 3·74. Lustre, vitreous. Colour, bright green, varying in shade according to the thickness. Streak, green. Refractive index, 1·846. Shows optical anomalies.

[1] From loss on ignition of a glass tube containing the mineral and a plug of dry sodium carbonate. A direct determination of the water made on 0·3464 gram by Penfield's method gave as low a percentage as 12·56, but there is reason to fear that some loss of water may have occurred.

[2] Min. Mag., 1899, vol. xii, p. 110.

Phenacite and other minerals from German East Africa.

By L. J. Spencer, M.A., F.G.S.
Assistant in the Mineral Department of the British Museum.

[Read March 15, 1905.]

A SMALL collection of minerals, together with other natural history specimens, has recently been acquired by the British Museum from the Rev. A. North Wood, a missionary in the Usagara (Ussagara) province of German East Africa. Mr. Wood's station is situated at Itumba, and the specimens had been brought to him by the natives from the surrounding district, mainly from places between Mamboya and Mpapwa, which lie on the caravan route from the coast opposite Zanzibar westwards into the interior to Lake Tanganyika.

The rocks of the district are biotite-gneiss and hornblende-gneiss, the latter with small garnets[1].

Phenacite from Kisitwi Mountains[2].—A single isolated crystal[3] measuring about $1\frac{1}{2}$ cm. in length by rather less than 1 cm. in diameter. It is perfectly colourless and transparent, and is bounded by numerous bright crystal-faces: it had been mounted as a pendant. It is a doubly terminated crystal, but at the end where it was attached to the matrix only a few faces are developed.

The following forms are present:—

Hexagonal prisms—

$a = \{10\bar{1}\} = \{11\bar{2}0\}$ $\quad$ $m = \{2\bar{1}\bar{1}\} = \{10\bar{1}0\}$

Rhombohedra of the first order—

$r = \{100\} = \{10\bar{1}1\}$ $\quad$ $z = \{22\bar{1}\} = \{01\bar{1}1\}$

$d = \{110\} = \{01\bar{1}2\}$ $\quad$ $\mu = \{11\bar{1}\} = \{02\bar{2}1\}$

Rhombohedra of the second order—

$p = \{210\} = \{11\bar{2}3\}$ $\quad$ $p_1 = \{201\} = \{2\bar{1}\bar{1}3\}$

Rhombohedra of the third order (hemi-scalenohedra)—

$s = \{20\bar{1}\} = \{21\bar{3}1\}$ $\quad$ $s_1 = \{2\bar{1}0\} = \{3\bar{1}\bar{2}1\}$

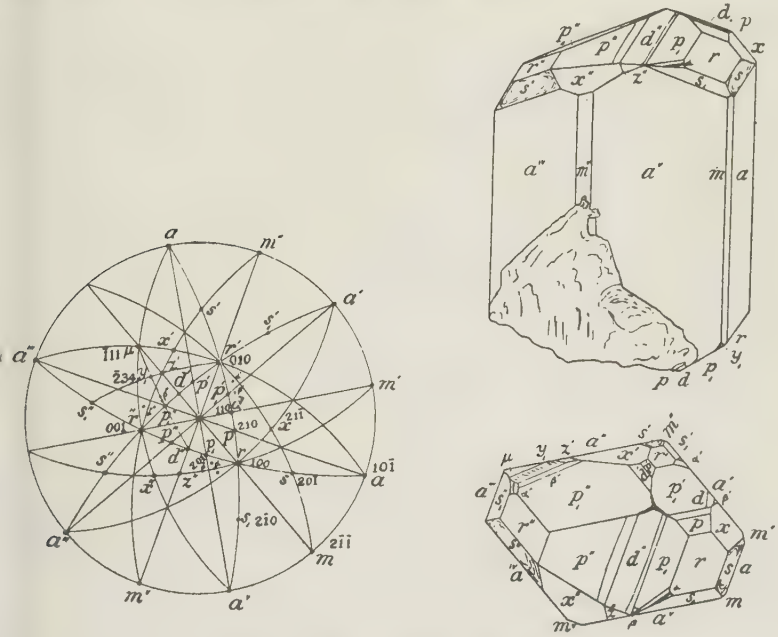
$x = \{21\bar{1}\} = \{12\bar{3}2\}$ $\quad$ $y_1 = \{4\bar{2}3\} = \{6\bar{5}\bar{1}5\}$

[1] C. Dantz, Mitth. Deutschen Schutzgebieten, 1902, vol. xv, p. 52 (Abstract in Zeits. prakt. Geol., 1902, Jahrg. x, p. 306).

[2] The Kisitwi range extends between Rubeho and Mulale (or Mlali); there is also a small village of the same name.

[3] British Museum, No. 1905,115.

The form y_1 $\{42\bar{3}\}$, which is new for phenacite, is represented by two small and somewhat rounded faces, situated at opposite ends of the crystal and parallel to one another. The face in the position $(\bar{2}34)$ was observed to lie in the zones $[d'' p_1''] = [101, 012]$ and $[r' z'] = [010, \bar{1}22]$: it is inclined at 6° 16′ to z' and at 20° to p_1''. The form μ $\{11\bar{1}\}$ is represented by only one face, which is very rough and reflects no image. z $\{22\bar{1}\}$ has only two faces, one of which is quite small.



Phenacite from German East Africa.
(Stereographic projection, clinographic drawing, and plan[1].)

Two faces of the prism m are absent. All the other rhombohedra given in the above list are each represented on the top of the crystal by three well-developed faces. At the opposite, attached end of the crystal some of the parallel faces are present; but a face of s_1 is missing from an edge between r and a. Apart from these accidental omissions of faces, the crystal is clearly rhombohedral with parallel-faced hemihedrism, possessing only a triad axis and a centre of symmetry.

[1] The method of giving a plan of the crystal together with the clinographic drawing was employed by N. I. Koksharov, in 1853, in his 'Materialien zur Mineralogie Russlands' (compare this volume, p. 44).

The faces of the complementary forms p and p_1 show little or no difference in surface characters, but, as may be seen from the figure, those of the latter are somewhat the larger in each of the three pairs. The faces of s and s_1 are equal in size and brightness; but whilst those of s_1 are even, those of s are rounded with platy layers of growth. There are no indications of the presence of the form complementary to x, though near by this position there are some irregular planes and rounded surfaces. The two complementary rhombohedra of phenacite have been distinguished by some authors according to whether they lie on the right-hand or on the left-hand side of r. Thus in the accompanying figures and projection x lies on the right of r; but it must be remembered that at the other end of the crystal x lies on the *left* of r.

Several good readings of the angles between the faces were obtained. Thus the angles over the six edges rp at the top of the crystals were determined as 20° 4′, 20° 6′, 20° 5′, 20° 5′, 20° 4½′, 20° 4′; and the three angles pp_1'' over the apex as 47° 38½′, 47° 38′, 47° 37½′. From the mean value $pp_1'' = 47° 38'$ is calculated $rp = 20° 5'$, agreeing with the mean of the measured angles. The corresponding angles given by Koksharov in 1857 for phenacite from the Urals, and adopted for the species in the textbooks, are 47° 34′ and 20° 4′. (Miller, in 1852, gave 47° 30′ and 20° 3′.)

The images reflected from the faces are often very good, though not always single. Portions of the two faces lettered d'' and p'' in the figures are replaced by smooth and well-defined vicinal faces, which give sharp images and lie accurately in the zone $[rr'']$. The vicinal face on d'' makes a salient angle of 56′ with this face; and that on p'' gives two images at 44½′ and 1° 0′ from the true position of p''.

Associated with the three faces of the form p_1 there are also three bright vicinal faces β, β', β'', which lie in the zones $[s_1\ d''\ p_1''\ y_1]$, &c., and are inclined to p_1 at about 3°: they are slightly rounded in these zones, the face in the position β'' being more rounded than the other two and giving a band of reflected light between 3° and 6° from p_1''.

Another set of small bright faces a, a', a'', somewhat similar to the last in character, replace the three corners $(r\ p_1\ s_1)$, &c. From each face of the form p_1 these faces form a banded zone; the angles measured for the more definite images in each being:

$p_1 a = 6° 43'$, 10° 21′, and 12° 56′.
$p_1' a' = 7° 24'$. $(r' a' = 14° 49'.)$
$p_1'' a'' = 6°$ and 13°.

The middle one of the three narrow faces at a, which gives the reading $\alpha = 10° 21'$, lies in the zone $[r z'']$ and makes with r an angle of 13° 9′: it therefore has the indices $(7\bar{1}2) = (8\bar{3}5\bar{8})$. The indices of the zone $[p_1 a]$ will then be $[13\bar{2}]$. The only other face on the crystal which should lie in this zone is μ $(\bar{1}11)$, but as this happens to be the only face which gives no reflected image this zonal relation could not be tested: some of the scattered and banded images reflected from the rounded surfaces on y_1 were, however, observed to lie in this zone.

Many of the edges between the faces of the crystal are perfectly sharp; but others, especially those between the prism and rhombohedron faces and those at the apex of the crystal, are rounded as if by corrosion. These rounded surfaces are quite bright, and reflect numerous scattered images. Some of the vicinal faces noted above are therefore probably of the nature of prerosion faces. They conform in their arrangement with the symmetry of the crystal.

The faces of the crystal are not marked with any definite etched figures. They are usually quite smooth and bright, but when examined closely many of them show duller and brighter areas with a patchy distribution.

The refractive indices for sodium light were determined as

$$\omega = 1{\cdot}653 \qquad \epsilon = 1{\cdot}672$$

but the images seen through the natural prism-faces being rather scattered, these results are only approximate. The specific gravity of the crystal is 2·8, this low value being readily accounted for by the numerous cavities. The crystal readily becomes electrified when rubbed.

The large number of cavities, some of them of considerable size, present in the crystal are of various shapes: (*a*) small and rounded; (*b*) lamellar, with surfaces parallel to the faces s and s_1, and bounded at the edges by small bright planes; (*c*) long and tubular, parallel to the triad axis of the crystal. Many of the cavities contain small black spots and globules of carbonaceous (?) material, and others contain brown films of iron oxide. A few contain a liquid with a bubble of gas, which disappear when the crystal is held in the warm hand; the liquid is therefore carbon dioxide.

Corundum from Mulale (eight miles west of Kisitwi).—Isolated crystals, 2–3 cm. in length, of a rose-red or flesh-red colour, and opaque or only slightly translucent. The predominating form is a steep hexagonal bipyramid $\nu\{1{\cdot}13{\cdot}\bar{1}\bar{1}\} = \{44\bar{8}1\}$, with faces inclined to the basal plane at about 84°. Other forms present are the basal pinacoid $c = \{111\} = \{0001\}$, the rhombohedron $r = \{100\} = \{10\bar{1}1\}$, and the hexagonal

bipyramid $n = \{13\bar{1}\} = \{22\bar{4}3\}$. Parting planes parallel to the rhombohedron r are sometimes present.

The faces of the crystals are curiously marked by a network of ridges, giving rise to a number of shallow pits with flat bottoms. These are probably the impressions of a granular aggregate of crystals in which the corundum crystals were originally embedded. In fact, there are attached to the surface of the crystals, or enclosed in them, several small grains or rounded crystals of a black, lustrous mineral, which proved on examination to be *rutile*.

Tourmaline from Kisitwi Mountains.—Isolated crystals measuring about 2 cm. across. They are jet-black and opaque, and have bright faces. One doubly terminated crystal is a short prism with the forms $a = \{10\bar{1}\} = \{11\bar{2}0\}$, $m = \{2\bar{1}\bar{1}\} = \{10\bar{1}0\}$, $r = \{100\} = \{10\bar{1}1\}$, and $c = \{111\} = \{0001\}$, the last being developed at one end only of the crystal. Another crystal shows at one end large smooth faces of $u = \{03\bar{2}\} = \{32\bar{5}1\}$ and $r = \{100\} = \{10\bar{1}1\}$; striated prism-faces are also present.

Tourmaline is also found in the Kiboriani Mountains.

Amethyst from Midindo (between Mamboya and Kitangi).—Small (1–2 cm. across), isolated bipyramidal crystals with prism-faces. They are transparent and of fairly good colour; the colour varies, however, in intensity, and in places the crystals are colourless. Numerous needles (of göthite?) are enclosed in the crystals.

Albite from the Itumba district.—An isolated crystal measuring $3 \times 2 \times 1\frac{1}{2}$ cm. It is white and only slightly translucent, and is bounded on all sides by crystal-faces belonging to the forms c {001}, b {010}, m {110}, M {1$\bar{1}$0}, e {021}, n {02$\bar{1}$}, p {$\bar{1}$11}, o {1$\bar{1}$1}, x {$\bar{1}$01}, y {20$\bar{1}$}. All the faces, except b, are striated by repeated twinning on the albite-law. The cleavage-angle bc was measured as 86° 15′, and the angle between two c cleavages across a plane of twinning as $7\frac{1}{4}$°. The angles of optical extinction on c and b are 4° and 16° respectively with reference to the edge b/c. These determinations agree well with the constants recorded for albite, but the specific gravity of 2·55 is rather low, being less than that of orthoclase.

Orthoclase from the Itumba district.—A cleavage fragment measuring $3\frac{1}{2}$ cm. across and 1 cm. in thickness. It is milky-white and translucent, and has a pearly lustre on the basal (c) cleavage, thus somewhat resembling moon-stone in appearance. Under the microscope it shows a microperthitic structure, owing to the enclosure of spindle-shaped bodies parallel to the hemi-orthodome (80$\bar{1}$): the angle between the

basal plane and (80$\bar{1}$) was measured under the microscope as 73°. The extinction angle on the plane of symmetry is +12° measured to the edge *c*/*b*; the plane of the optic axes is perpendicular to the plane of symmetry. The cleavage-angle *bc* was determined on the goniometer to be 90°. Specific gravity, 2·65.

Kaolin from Ikwamba (between Uponera and Kisitwi).—An incoherent mass of pure white material. Throughout the whole mass there is a minute lattice-like or cellular structure marked out by three sets of planes respectively parallel to the planes (010), (001), and (80$\bar{1}$) of orthoclase. The angle between (001) and (80$\bar{1}$) was determined to be about 73°, and the angles between these planes and (010) are 90°. The mass is thus the remains of a large crystal of orthoclase, in which the alteration to kaolin had taken place along the cleavage and parting planes.

Diopside from between Kisitwi and Mulale.—An aggregate of small indistinct crystals of a pale green colour.

Muscovite from Uluguru Mountains.—In addition to the species mentioned above, the collection also contains a sheet of mica from the Uluguru Mountains, in the Ukami province, and about 100 kilometres to the south-east of Itumba. Mr. Wood, however, states that mica is also found in the Itumba district.

The specimen is a trimmed sheet measuring 19 by 12 cm. It is transparent, with a slight smoky shade of colour, without flaws, and readily cleavable into very thin, elastic leaves. The optic axial angle (2E) is about 60°.

A detailed description of the occurrence of large sheets of mica in the pegmatite-veins traversing the gneiss of the Uluguru Mountains has been given by W. Bornhardt.[1] Sheets of commercial value have been exported from this locality.

[1] W. Bornhardt, 'Zur Oberflächengestaltung und Geologie Deutsch-Ostafrikas,' Berlin, 1900, p. 328 (abstract in Zeits. Kryst. Min., 1902, vol. xxxvi, p. 422; see also Zeits. prakt. Geol., 1903, Jahrg. xi, p. 199).

Notes on some Binnenthal minerals (Ilmenite, Seligmannite, Marrite, &c.)

By R. H. Solly, M.A.

[Read November 14, 1905.]

Ilmenite.[1]

Some very brilliant and well-modified crystals of ilmenite, recently found in the neighbourhood of the Ofenhorn, are of interest in that they exhibit a well-marked parallel hemihedrism and show the presence of a number of new forms. Although constantly sought for, it is more than fifteen years since crystals of this mineral were last found in the Binnenthal. The crystals described by H. Bücking[2] in 1877 appear to differ in habit from those of the new find.

The crystals now described are attached to a matrix of mica-schist, and the associated minerals are quartz, adularia, magnetite, and mica. The plane (111) of the ilmenite is largely developed, and is finely striated parallel to its edges of intersection with the planes of the form $n = \{31\bar{1}\}$

[1] The crystal described above, and the specimen from which it was taken, have been acquired by the British Museum. The crystal was measured on the three-circle goniometer by Mr. G. F. Herbert Smith, and the following additional new forms were observed :—$q = \{\bar{3}31\} = \{\bar{6}241\}$, $k = \{\bar{4}52\} = \{3121\}$, $\Gamma = \{3\bar{1}\bar{1}\} = \{40\bar{4}1\}$, and $d = \{411\} = \{10\bar{1}2\}$. The faces were in all cases small, but gave distinct reflections of the collimator-slit. The measurements were made from the large basal plane $c = \{111\} = \{0001\}$, and the azimuths were determined from the nearest zone containing a pole of the form $a = \{10\bar{1}\} = \{11\bar{2}0\}$. The calculated values were computed from Koksharov's fundamental angle adopted in Dana's 'System of Mineralogy,' 6th edit., 1892.

[2] Zeits. Kryst. Min., 1877, vol. i, p. 576.

Form.	Indices.		Calculated Values.		Observed Means.		Number.	Limits of Observation	
	Rhombohedral.	Hexagonal.	Azimuth.	Distance.	Azimuth.	Distance.		Azimuth.	Distan
Γ	$3\bar{1}\bar{1}$	$40\bar{4}1$	30° 0′	81° 6½′	30° 0′	81° 5′	1		
d	411	$10\bar{1}2$	,, ,,	38 38	,, ,,	38 30	1		
q	$\bar{3}31$	$\bar{6}241$	10 53½	83 16	10 40	83 9	3	10° 34′–10° 45′	83° 4′–8
k	$\bar{4}52$	3121	,, ,,	76 42	,, ,,	76 41	2	,, ,, ,,	76 40, 7

The forms present are the following, the six in the second column being new for ilmenite :—

$c = \{111\} = \{0001\}$	$a = \{992\} = \{0{\cdot}7{\cdot}7{\cdot}20\}$
$a = \{10\bar{1}\} = \{11\bar{2}0\}$	$X = \{513\} = \{4483\}$
$r = \{100\} = \{10\bar{1}1\}$	$\gamma = \{21\bar{1}\} = \{1232\}$
$s = \{11\bar{1}\} = \{02\bar{2}1\}$	$\delta = \{53\bar{1}\} = \{24\bar{6}7\}$
$n = \{31\bar{1}\} = \{22\bar{4}3\}$	$\beta = \{3{\cdot}8{\cdot}13\} = \{5{\cdot}5{\cdot}10{\cdot}24\}$
	$h = \{3\bar{1}2\} = \{41\bar{5}0\}$

The forms n, X, γ, δ, and β are hemihedral with parallel faces, being rhombohedra of the third order or hemi-scalenohedra. The faces X, n, and β lie in the zone $[ca]$, X and n being on one side of c and β on the other side. The face a lies between the faces c and s in the zone $[cr]$: γ lies between n and s, and δ is near to this in the zone $[c\delta\gamma]$. On the crystal (fig. 1) which was measured there are also some very small faces between c and n, and between c and s. The angles observed on this crystal are given below.

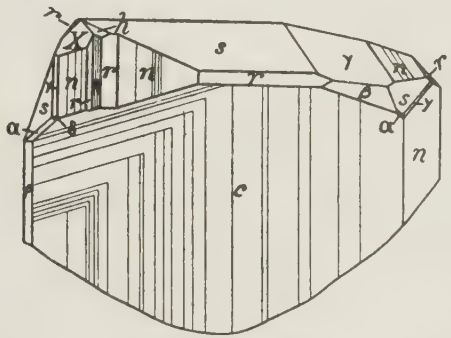


Fig. 1.—Ilmenite.

	Calculated.[1]	Measured.
$cr =$	57°58½′	57°58′, 57°59′, 57°58′.
$ca =$	29 14	29°12′, 29°10′, 29° (max. light).
$cs =$	72 38	72°38′, 72°38′, 72°38′.
$cc' =$	180 0	180°0′.
$cn =$	61 33	61°33′, 61°34′, 61°31′, 61°33′.
$cX =$	74 50½	74°50′, 74°51, 75° (max. light).
$ca =$	90 0	90° (max. light).
$c\beta =$	29 58½	30°0′, 29°59′, 29°57′, 30° (poor image).
$c\delta =$	50 23½	50°22′, 50°30′ (faint), 50° (max. light).
$c\gamma =$	64 41½	64°41′, 64°40′ (faint), 64°42′.

[1] Calculated from the element of N. I. Koksharov, 'Materialien zur Mineralogie Russlands,' 1870, vol. vi, p. 357.

$as =$	34 15	34°16′, 34°18′.
$a\gamma =$	53 43	53°43′, 53°43′.
$an =$	63 55	63°55′, 63°55′.
$ar =$	90 0	90°0′, 90°0′.

Seligmannite.

Hitherto[1] only twinned crystals of this rare mineral have been discovered. In August, 1905, however, a large untwinned crystal was found in the Lengenbach quarry. It was met with as a single crystal in the iron-stained dolomite, which seldom carries any of the numerous sulpharsenites. The crystal measures $10 \times 7 \times 5$ mm., and its actual shape is represented in fig. 2. Owing to the absence of twinning and of cleavage, it appeared at first sight to be a large and highly modified crystal of tennantite ('binnite'), but when measured the angles were seen to be those of seligmannite.

The planes of the form $\{110\}$ are largely developed. Those of the forms $\{131\}$, $\{121\}$, and $\{111\}$ are finely striated parallel to their mutual intersections; and those of $\{031\}$ are striated parallel to their intersection with $\{010\}$.

Forty-five forms are present on the crystal, of which twenty-two are new; the latter are distinguished by an asterisk in the following list of forms. Fifty-seven forms have now been observed on this mineral, but only twenty-five of these are met with on bournonite, which Professor Baumhauer has suggested to be isomorphous with seligmannite.

$a = \{100\}$	$*F = \{061\}$	$*V = \{12{\cdot}1{\cdot}2\}$	$s = \{212\}$
$b = \{010\}$	$\Sigma = \{031\}$	$*S = \{713\}$	$*N = \{323\}$
$c = \{001\}$	$n = \{011\}$	$*T = \{613\}$	$D = \{322\}$
	$\kappa = \{013\}$	$*P = \{611\}$	$\phi = \{113\}$
$i = \{130\}$		$*X = \{14{\cdot}3{\cdot}6\}$	$u = \{112\}$
$f = \{120\}$	$*G = \{601\}$	$*U = \{413\}$	$y = \{111\}$
$m = \{110\}$	$*H = \{703\}$	$*O = \{313\}$	$*M = \{233\}$
$*l = \{320\}$	$*I = \{201\}$	$*Y = \{312\}$	$\rho = \{121\}$
$e = \{210\}$	$o = \{101\}$	$C = \{311\}$	$*L = \{131\}$
$\eta = \{310\}$	$*h = \{203\}$	$*Q = \{733\}$	$*Z = \{261\}$
$A = \{410\}$	$x = \{102\}$	$v = \{211\}$	$*K = \{161\}$
$*E = \{610\}$	$\epsilon = \{103\}$	$*R = \{533\}$	

[1] H. Baumhauer, Sitz.-ber. Akad. Wiss. Berlin, 1901, p. 110; 1902, p. 611. R. H. Solly, Min. Mag., 1903, vol. xiii, p. 336; 1905, vol. xiv, p. 82.

The following angles were measured on this crystal:—

	Calculated.	Measured.		Calculated.	Measured.
Zone [100,010].			Zone [100,012].		
100 : 610	8°45′	9° ′	100 : 12.1.2	10°53′	11° ′
: 410	13 0	13 5	: 14.3.6	26 18½	27
: 310	17 6½	17 10	: 312	37 34	38
: 210	24 47	24 48	: 212	49 5	49 2
: 320	31 37	31 37	: 112	66 34	66 35
: 110	42 43	42 43½	: 012	90 0	—
: 120	61 34	61 40	Zone [100,011].		
: 130	70 9	70 9½	100 : 611	13 10½	13
: 010	90 0	90 0	: 311	25 4½	25 4
Zone [100,001].			: 733	31 2	31
100 : 601	9 59½	10	: 211	35 3½	35 3
: 703	24 22½	24 30	: 533	40 6	40
: 201	27 51½	27 51	: 322	43 6	43 6
: 101	46 35½	46 35	: 111	54 32	54 33
: 203	57 46	57 50	: 011	90 0	90 0
: 102	64 41½	64 45	Zone [010,101].		
: 103	72 30	72 31	010 : 161	14 43	14
: 001	90 0	90 0	: 131	27 43	28 1
Zone [010,001].			: 121	38 14½	38 14
010 : 061	10 48	11	: 111	57 36½	57 37
: 031	20 53½	20 52	: 323	67 4½	67 8
: 011	48 52	48 52	: 212	72 24	72 21
: 013	73 46	73 46	: 313	78 3½	78 4
: 001	90 0	90 0	: 101	90 0	90 0
Zone [100,013].					
100 : 713	25 16½	25	(233) lies in zones [121,112], [011,111]; (261) in zones [130,131], [010,211]; and (161) in zones [130,031], [010,131].		
: 613	28 51	29			
: 413	39 34	39 30			
: 313	47 46	47 45			
: 113	73 10	73 10			
: 013	90 0	90 0			

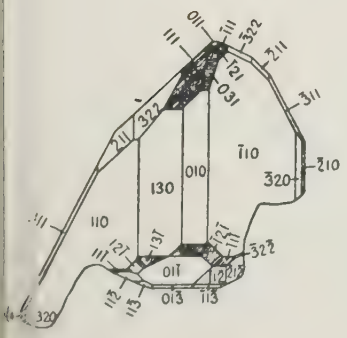


Fig. 2.—Seligmannite.

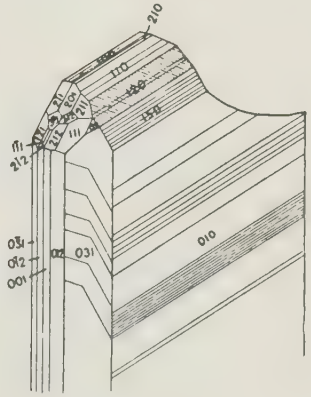


Fig. 3.—Marrite.

Marrite.

During the summer of 1905 I came across only two crystals of this very rare mineral, of which there is still insufficient material for a chemical analysis. The two new crystals differ in habit from those previously described (this vol. p. 76).

Crystal No. 1 (fig. 3) was deposited in a cavity of the white dolomite, and in appearance closely resembles a tabular crystal of dufrenoysite. The faces in the zone [100,010] are deeply striated parallel to their mutual intersections; the face (031) is largely developed and is marked with obliquely placed striations.

Crystal No. 2, with a sharply pointed oblique habit, was deposited in the centre of a large hollow crystal of rathite. On this crystal the forms {170}, {150}, {140}, {031}, and {083} are largely developed.

The following list of thirty-four forms observed on the two crystals includes seven which are new.

$a = \{100\}$	$7r = \{170\}$	$*4k = \{041\}$	$-p = \{111\}$	$+p = \{1$
$b = \{010\}$	$5r = \{150\}$	$\frac{7}{2}k = \{072\}$	$-2t = \{212\}$	$+2q = \{1$
$c = \{001\}$	$4r = \{140\}$	$3k = \{031\}$	$-2u = \{211\}$	
	$3r = \{130\}$	$*\frac{8}{3}k = \{083\}$	$-2q = \{121\}$	
$-2h = \{201\}$	$2r = \{120\}$	$\frac{7}{3}k = \{073\}$	$*-3q = \{131\}$	
$+2h = \{20\bar{1}\}$	$r = \{110\}$	$2k = \{021\}$	$*-5q = \{151\}$	
$+h = \{10\bar{1}\}$	$\frac{3}{2}s = \{320\}$	$k = \{011\}$	$*-w = \{271\}$	
	$2s = \{210\}$	$\frac{2}{3}k = \{023\}$	$*-v = \{312\}$	
	$*3s = \{310\}$	$\frac{1}{2}k = \{012\}$		

The plane 312 is well developed and lies in the zones [201,111] and [212,100].

In the following list of measured angles it will be noticed that the angles measured in the zone [010,201] differ somewhat from the calculated values. The same difference was observed in a crystal previously measured, and it would seem that the elements have not been quite correctly chosen.

	Calculated.	Measured. I.	Measured. II.
Zone [100,001].			
(100) : (201)	30° 58′	30° 57′	—
: (001)	88 45	88 46	—
(100) : (20$\bar{1}$)	31 38	31 37	—
Zone [010,001].			
(010) : (041)	82 53	22 45	—
: (072)	21 5½	31 3	31° 3′
: (031)	35 8	35 6	35 8
: (083)	38 22	—	38 21
: (073)	42 8	—	42 30
: (021)	46 32½	46 22	46 28
: (011)	64 39	—	64 30
: (023)	72 28½	73	—
: (012)	76 40¼	76 48	—
: (001)	90 0	90	—
Zone [010,201].			
(010) : (271)	31 10½	30 13	—
: (211)	76 43	76 17	—
: (201)	90 0	90 0	—

	Calculated.	Measured. I.	Measured. II.
Zone [010,100].			
(010) : (170)	13°55½′	—	13°59′
: (150)	19 8½	19° 8′	19 13
: (140)	23 27	23 30	23 27
: (130)	30 3	30 3	30 5
: (120)	40 57	41 0	40 53
: (110)	60 3	60 5	60 2
: (320)	68 59	69 1	—
: (210)	73 55½	73 50	—
: (310)	79 8	79 2	—
: (100)	90 0	90	—
Zone [010,101].			
(010) : (151)	28 55	28 53	—
: (131)	42 38½	42 38	—
: (121)	54 5½	54 6	—
: (111)	70 6	70 7	—
: (212)	79 44½	79 46	—
Zone [010,10$\bar{1}$].			
(010) : (12$\bar{1}$)	53 30	—	53 25
: (11$\bar{1}$)	69 42	—	69 45
: (10$\bar{1}$)	90 0	—	90

Proustite.

This mineral has not hitherto been recorded from the Binnenthal. A single, minute crystal was found attached to a crystal of rathite[1], which was taken in 1905 from the white crystalline dolomite of the Lengenbach quarry. The crystal is a hexagonal prism $a\ \{10\bar{1}\}$ terminated by the rhombohedron $r\ \{100\}$. The prism-angle was measured as 60° 0′, and the angles between the prism and rhombohedral faces as 53° 57′ and 53° 58′ (from the element given by Miers, $ar = 53° 54'$). The crystals of the two minerals are so arranged with respect to each other that the prism-edges are parallel.

Trechmannite.

During the season 1905 very few crystals of the new red minerals described in the last number of this Magazine have been found in the Lengenbach quarry. One crystal, which was at first thought to be hutchinsonite, proved on measurement to be the very rare mineral trechmannite. It was found attached to a crystal of tennantite ('binnite'). The crystal is very irregularly developed; it shows the forms $a\ \{10\bar{1}\}$, $n\ 2\bar{1}\bar{1}\}$, $r\ \{100\}$, and $x = a\ \{21\bar{2}\}$. The faces of $x = a\ \{21\bar{2}\}$ ar-

[1] The rathite crystal is similar to that represented in fig. 5, Min. Mag., 1901, vol. xiii, Plate III.

large and belong to a trigonal trapezohedron. This trapezohedral-hemihedral type of symmetry of trechmannite (like that of quartz and cinnabar) had already been noticed by Mr. G. F. Herbert Smith on the crystals previously described by me (this vol. p. 75).

Hyalophane and Barytes.

Some of the hyalophane crystals found during 1905 in the Lengenbach quarry are of a pale green colour, and had been mistaken for green tourmaline. Pale green crystals of barytes have also been found. At this locality the crystals of barytes are usually colourless, though sometimes bluish-grey in colour.

Montreux Club,
Territet, Switzerland.

On the method of minimum deviation for the determination of refractive indices.

With a diagram (Plate IV).

By G. F. Herbert Smith, M.A., F.G.S.
Assistant in the Mineral Department of the British Museum.

[Read January 23, 1906.]

A DETERMINATION of the refractive power, which need be accurate to the second place of decimals only, is of considerable service for the discrimination of transparent substances, such as, in particular, faceted gem-stones. If the substance be so highly refractive that a total-reflectometer be not available, the method of minimum deviation is the simplest that can be used. Although the well-known formula

$$\mu = \frac{\sin\frac{A+D}{2}}{\sin\frac{A}{2}},$$

where A is the angle of the prism, D the minimum deviation, and μ the index of refraction, is only strictly true when the plane bisecting the prism-angle is one of symmetry with regard to the optical indicatrix, yet the value so given is sufficiently correct for the purpose. It is the large errors which have to be avoided. When there are many faces in the same zone, the incident and emergent faces corresponding to the refracted image under observation are not easily identified, and mistakes may be made in the arithmetical computation even though the formula given above is so simple. Any process or device, therefore, which will add to the certainty of arriving at a correct result may be of service.

In the form of goniometer which is employed for this work, the telescope and graduated scale can rotate independently about the same axis. The procedure should be as follows:—The telescope is clamped in the position directly opposite to the collimator, and the scale rotated until it reads zero. The latter is now clamped and the telescope turned in the direction of increasing readings until it reaches the position of minimum deviation for some refracted image; the corresponding reading of the scale gives at once the angle D required. The stone and scale both remaining fixed, the telescope is turned to the position in which

the image reflected from the face of incidence is bisected by the cross-wires. This face should, if possible, always be one readily recognized, for instance the table facet of a cut stone; but in any case there should be little difficulty in identifying the face, since, if the telescope be rotated so that the images from consecutive faces are brought on to the cross-wires, it turns through double the angle between the faces in question, and therefore only one face will as a rule lie anywhere near a possible position. The telescope is in its turn clamped and the scale is read. The latter with the stone is rotated until the reading is that found for D. There should be in this position an image reflected from the face of emergence. The coincidence may not be exact because at minimum deviation a comparatively large rotation of the stone has no apparent effect on the position of the refracted image, apart from the fact that the formula already mentioned is not in general quite true. The difference between the last two readings gives the supplement of A. If this method be followed there will be no difficulty in correctly identifying the faces of the prism.

When the telescope is in the position for receiving the image reflected from the face of incidence the reading of the scale is theoretically $180°+A+D$. When the scale is rotated so that the image reflected from the face of emergence is on the cross-wires the reading is increased by $180°-A$, and thus we have $360°+D$ or D. Had the angle of minimum deviation been determined in the negative direction so that the reading of the scale was $360°-D$, we should have had instead $180°-(A+D)$ less $(180°-A)$ or $-D$, i. e. $360°-D$. The rule thus still holds good that the reading for the face of emergence is that previously found for the position of minimum deviation; and it remains true in the more general case, when the direct reading of the object-slit is any arbitrary angle and not zero.

In order to minimize the risk of errors in the computation, the author has prepared the diagram given on Plate IV. It is really a graphical interpretation of the formula

$$\mu = \frac{\sin\frac{A+D}{2}}{\sin\frac{A}{2}}$$

put into the form $$r = a\cos\theta + a\sin\theta\cot\frac{A}{2},$$

where $$\frac{r}{a} = \mu \text{ and } \theta = \tfrac{1}{2}D.$$

This may also be written in Cartesian co-ordinates

$$x^2+y^2 = ax+ay\cot\frac{A}{2},$$

whence we see that the formula thus expressed represents a family of circles, which pass through the origin and cut the axis of X at a distance a from the origin, and whose centres lie on the line $x = \frac{1}{2}a$. The family of circles are the curves running skew-wise across the diagram and have been drawn for every degree from $A = 10°$ to $A = 80°$. The radial lines are also drawn for every degree from $D = 10°$ to $D = 60°$. It may be noticed that the refractive index corresponding to any observed prism-angle and angle of minimum deviation within the given limits may be read off directly from the diagram to at least the second place of decimals. The range of the diagram includes refractive indices lying between 1·40 and 2·50.

NOTES.

The following deaths have to be recorded:—

Emil Wilhelm Cohen (1842–1905), since 1885 Professor of Mineralogy in the University of Greifswald; previously (1878–85) he was Extraordinary-Professor of Petrology at Strassburg. He was the author of numerous papers on meteoric irons, and his 'Meteoritenkunde', of which three parts were published between 1894 and 1905, unfortunately remains incomplete. He visited South Africa in 1872, and was the first to give a detailed scientific account of the diamond-fields; many of his early petrographical and mineralogical papers are descriptive of material from this region. He also published a large series of photographic illustrations of rock-sections and of meteorites. A detailed biographical notice, together with a list of his published works, is given by Professor W. Deecke, his successor at Greifswald, in the 'Centralblatt für Mineralogie, &c.' (1905, pp. 513–530).

Per Theodor Cleve (1840–1905), since 1874 Professor of Chemistry in the University of Upsala. He was distinguished as a chemist, especially in connexion with his researches on the rare earths, but was also a recognized authority on microscopic marine organisms and hydrography. He analysed and described several mineral species, and the mineral cleveite was named after him in 1878.

Jean Baptiste Henry Dufet (1848–1905), since 1885 Professor of Mineralogy in the École Normale Supérieure at Paris. He made numerous exact determinations of the physical constants of crystals, especially of the optical constants of isomorphous mixtures. A biographical notice, with portrait and list of published works, is given by Professor G. Wyrouboff (Bull. Soc. franç. Min., 1905, vol. xxviii, pp. 246–258).

A new and revised edition has appeared (1905) of Professor A. H. Church's well-known Handbook of Precious Stones, which first appeared in 1882 and has several times been reissued; it has now been enlarged from 112 to 140 pages. The coloured plate has been redrawn, new diagrams being given of the absorption spectra of almandine and zircon. In his preface the author points out that the value of the precious stones exported from Ceylon is usually very much under-estimated and con-

sidered of less importance than the graphite and pearls; as a moderate estimate he gives £300,000 as the value of the gem-stones (apart from pearls) annually exported.

New editions, in each case the fourth, have recently appeared of the following standard works: Professor P. Groth's 'Physikalische Krystallographie' (1905) has been increased by forty pages, there now being 820 pages as compared with 527 pages in the first edition of 1876. The principal alterations are in the optical portion. A distinction is now made between bivectorial and vectorial (e.g. pyro-electric) characters; and amongst the former a further distinction is made between physical characters of higher symmetry expressible by an ellipsoid (optical, electric, &c.) and those of lower symmetry (cohesion and elasticity).

The first volume, dealing with rock-forming minerals, of Professor H. Rosenbusch's 'Mikroskopische Physiographie der Mineralien und Gesteine' has now been split into two parts. The first part (1904) has been entirely rewritten by Professor E. A. Wülfing, and gives an excellent summary of the methods of investigation; while the second part (1905), descriptive of the rock-forming minerals, has been extensively revised and added to by Professor Rosenbusch himself.

New editions have also been issued of the textbooks of Mineralogy by Professor G. Tschermak (6th edit., 1905) and Professor Max Bauer (2nd edit., 1904).

An excellent volume on topographical mineralogy is the 'Mineralogia Groenlandica', by O. B. Boeggild, issued as No. 6 of the Contributions to Mineralogy from the Mineralogical and Geological Museum of the University of Copenhagen (Copenhagen, 1905, pp. xix + 625, with map). Being based on the rich collections of Greenland minerals, which have been gradually accumulated in the Copenhagen Museum during more than a century, the work contains much information not previously published: for instance, of the 119 figures of crystals 87 are new. The number of mineral species recorded with certainty is 162. The locality lists include both the new and the old spellings of place-names, and a map adds considerably to the usefulness of the volume. In the preface, which is written in English (the main part of the volume being in Danish), Professor N. V. Ussing gives some historical notes respecting the Copenhagen collections and the many collecting expeditions to

Greenland. Mineral specimens were early brought home by the Danish missionaries, but the first systematic collections were those made by C. L. Giesecke in 1806–1813, while more recent is the remarkably rich material collected by G. Flink in 1897.

A new journal entitled 'Economic Geology', published bimonthly at Lancaster in Pennsylvania, is devoted to mining geology and the systematic study of ore-deposits. In scope it is very much the same as the 'Zeitschrift für praktische Geologie'. The first two numbers, issued at the end of 1905, include several original papers by well-known American geologists, together with personal notes, abstracts, and reviews. Commencing with 1906, the 'American Geologist' will be incorporated with the new journal, and its final number will contain a general index to the thirty-six volumes which have been published during the last eighteen years (1888–1905).

The Mines Branch of the Canadian Department of the Interior has commenced the issue of a series of publications on the economic minerals of Canada. The two monographs which have already appeared (1905) deal with mica and asbestos (i. e. chrysotile), and are by Fritz Cirkel. These extend to 148 and 169 pages respectively, and are illustrated by numerous figures, plates, and maps. They give a description of the general characters, modes of occurrence, methods of mining, and working of the minerals. Much of the information is of a strictly practical character, and in places shows evidence of having been hurriedly put together.

'Minerales alcalinos y terrosos de Colombia' and 'Gemas y minerales litoides de la Republica de Colombia' are the titles of two pamphlets, by R. Ll. Codazzi, recently issued as parts of the 'Trabajos de la Oficina de Historia Natural' (Bogata, 1904). A brief description is given of the characters of American species of minerals, with notes on their occurrence at North and South American localities, and in particular those of Colombia.

Other South American publications bearing on mineralogy have also reached us from Peru; namely, the 'Boletín del Cuerpo de Ingenieros de Minas del Perú', of which twenty-six numbers have already appeared (Lima, 1902 and 1905) and several more are promised. These deal primarily with the mineral resources of the different provinces, whilst

others, for example No. 7 on 'El Cinabrio de Huancavelica', treat of a mineral of economic importance at a particular locality.

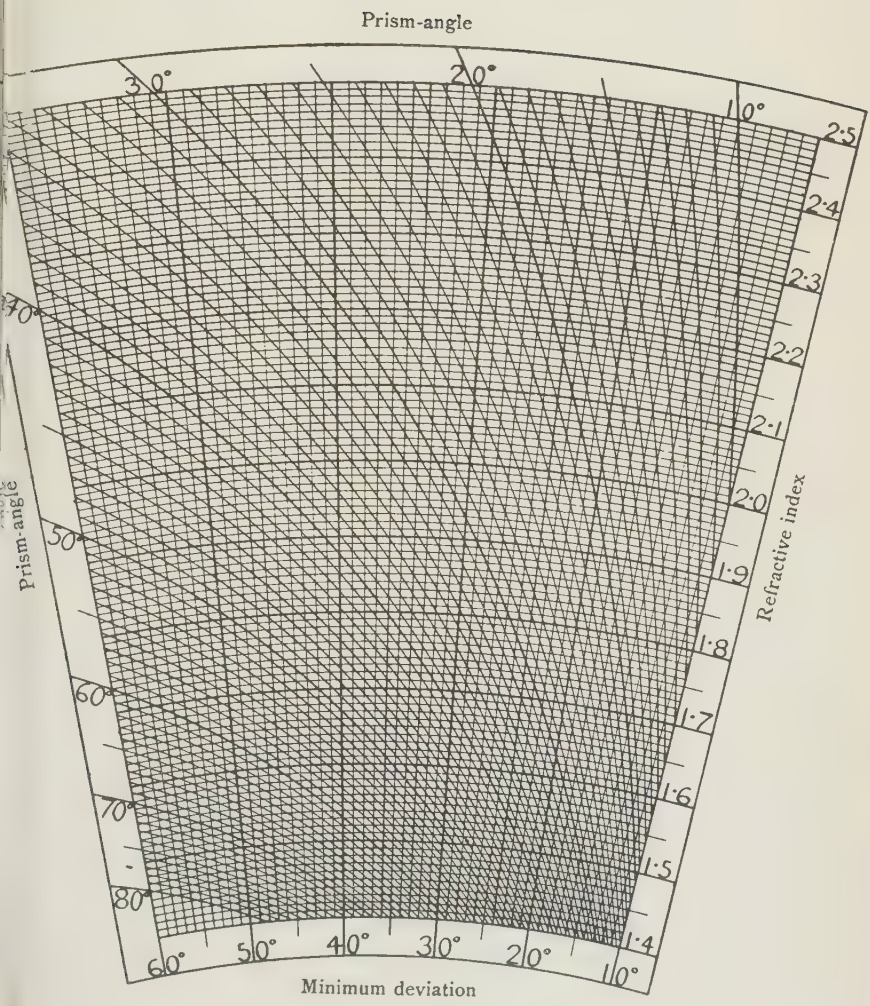
Although several artificial substances (tartaric acid, cane-sugar, &c.) are known to crystallize in the hemimorphic (sphenoidal) class of the monoclinic system, there is as yet no known example of this type of symmetry amongst minerals. Dr. H. Böckh ('Földtani Közlöny', Budapest, 1904, vol. xxxiv, p. 369) claims to have found an example in fichtelite, a hydrocarbon occurring in lignite. The crystals he describes exhibit the hemimorphic development of the faces and are pyro-electric, but they were artificially crystallized from a solution obtained by extracting a fichtelite-bearing lignite with ligroin, and can therefore scarcely be considered to be representative of a natural mineral.

The linear force exerted by growing crystals has been investigated by Drs. G. F. Becker and A. L. Day (Proc. Washington Acad. Sci., 1905, vol. vii, pp. 283–288). A weighted plate of glass was placed over a crystal of alum growing from solution, and it was found that a crystal 1 cm. in diameter could raise a kilogram weight through a distance of several tenths of a millimetre. The crystals grow with a cupped surface, and only a very narrow ring of material is in contact with the glass. The actual area of contact it was impossible to estimate, but it is so small that the force exerted by the growing crystal must amount to many pounds per square inch, being of the same order of magnitude as the resistance which the crystal offers to crushing stresses.

Attention is drawn to the geological importance of this force of crystallization, especially in connexion with the formation of quartz-veins and ore-deposits. If in quartz the force exerted during crystallization on the walls of the vein is comparable with the resistance which the material offers to crushing, then it must be considerable.

The so-called 'pine-apple' pseudomorphs, from the opal mines of White Cliffs in New South Wales, consist of precious opal with the form of acute four-sided pyramids of considerable size and arranged in radiating clusters. They have been examined by Jaquet, Weisbach, and Pelikan, who have variously suggested gypsum or sulphur for the original mineral, while Gürich compared them with the 'barley-corn' pseudomorphs of Sangerhausen. Recently Messrs. C. Anderson and H. S. Jevons

(Records of the Australian Museum, 1905, vol. vi, pp. 31–37, two plates) have measured the angles between the somewhat rounded faces and find that the form is monoclinic; they also observed traces of a distinct cleavage perpendicular to the plane of symmetry. The angles approach those of glauberite ($Na_2SO_4.CaSO_4$), and this, the authors conclude, was the original mineral of these pseudomorphs.



G. F. HERBERT SMITH : REFRACTIVE INDEX DIAGRAM.

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